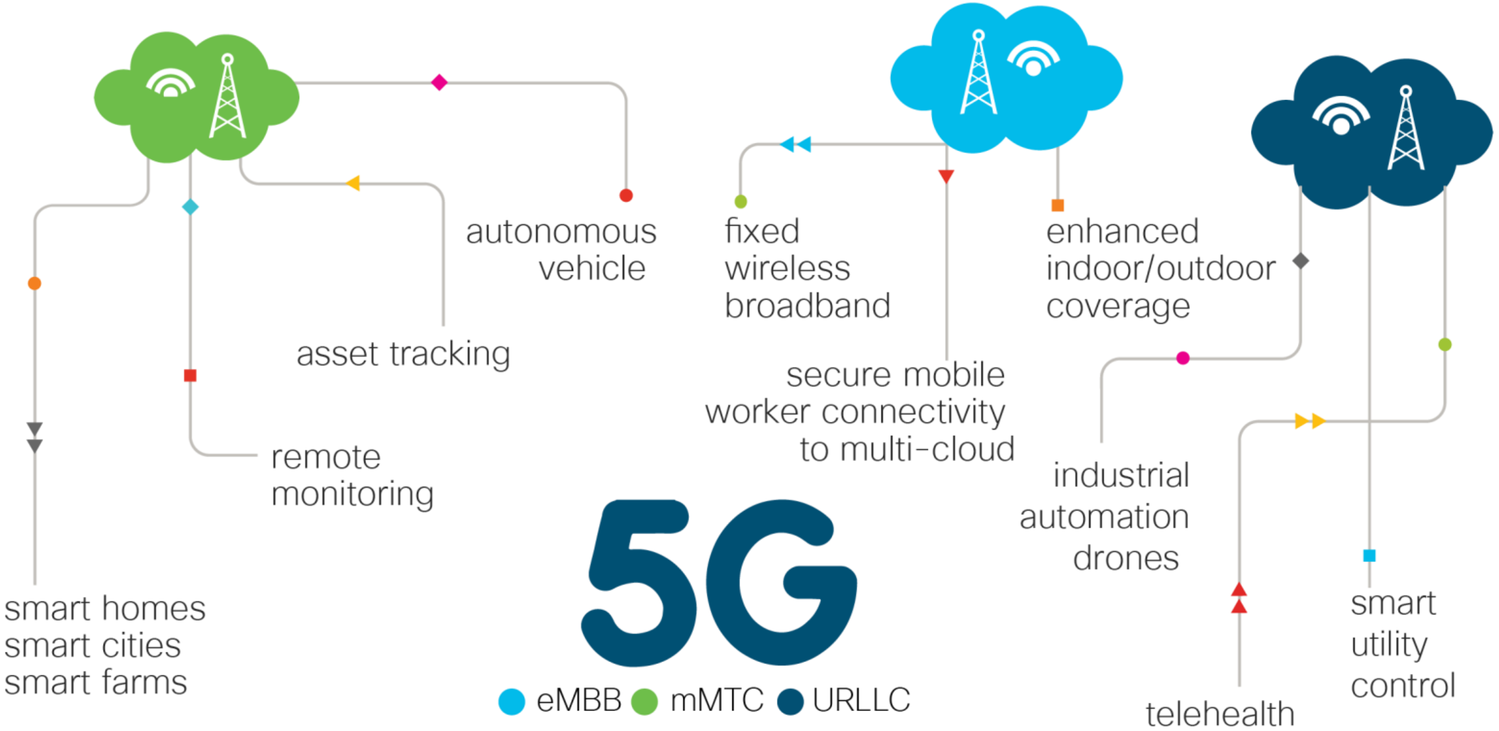
Converged SDN Transport

Cisco Systems
2019
Proposal

5G + Enterprise Service Opportunities

pursuit of productivity

through digitization



smart homes
smart cities
smart farms

remote
monitoring

asset tracking

autonomous
vehicle

fixed
wireless
broadband

secure mobile
worker connectivity
to multi-cloud

enhanced
indoor/outdoor
coverage

industrial
automation
drones

telehealth

smart
utility
control

● eMBB ● mMTC ● URLLC

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Use Cases : Video / VR / AR

- Need to increase Broadband Penetration ratio in Indonesia

VR (Virtual Reality)

- An interactive 3D image connected to a computer that users can manipulate to feel like they are in a different world
- Bandwidth requirement
  - 25 Mbps for low resolution
  - 80~100 Mbps for HD resolution
  - 600 Mbps for retinal resolution
- Latency requirement
  - 10 ~ 40 msec

AR (Augmented Reality)

- Enhanced user’s experience by adding virtual components as an overlay to the real world in order to make it more meaningful through the ability to interact with it
- Bandwidth requirement
  - 25 Mbps for low resolution
  - Upto several Gbps for retinal resolution
- Latency requirement
  - 1 msec

AR/VR proportion : 4.4% in 2022

Streaming TV

- BBC
  - 1.5 Mbps for SD
  - 2.75 Mbps for HD

- Netflix
  - 3 Mbps for SD
  - 5 Mbps for HD
  - 25 Mbps for UHD

# of UHD TV : 72% in 2022

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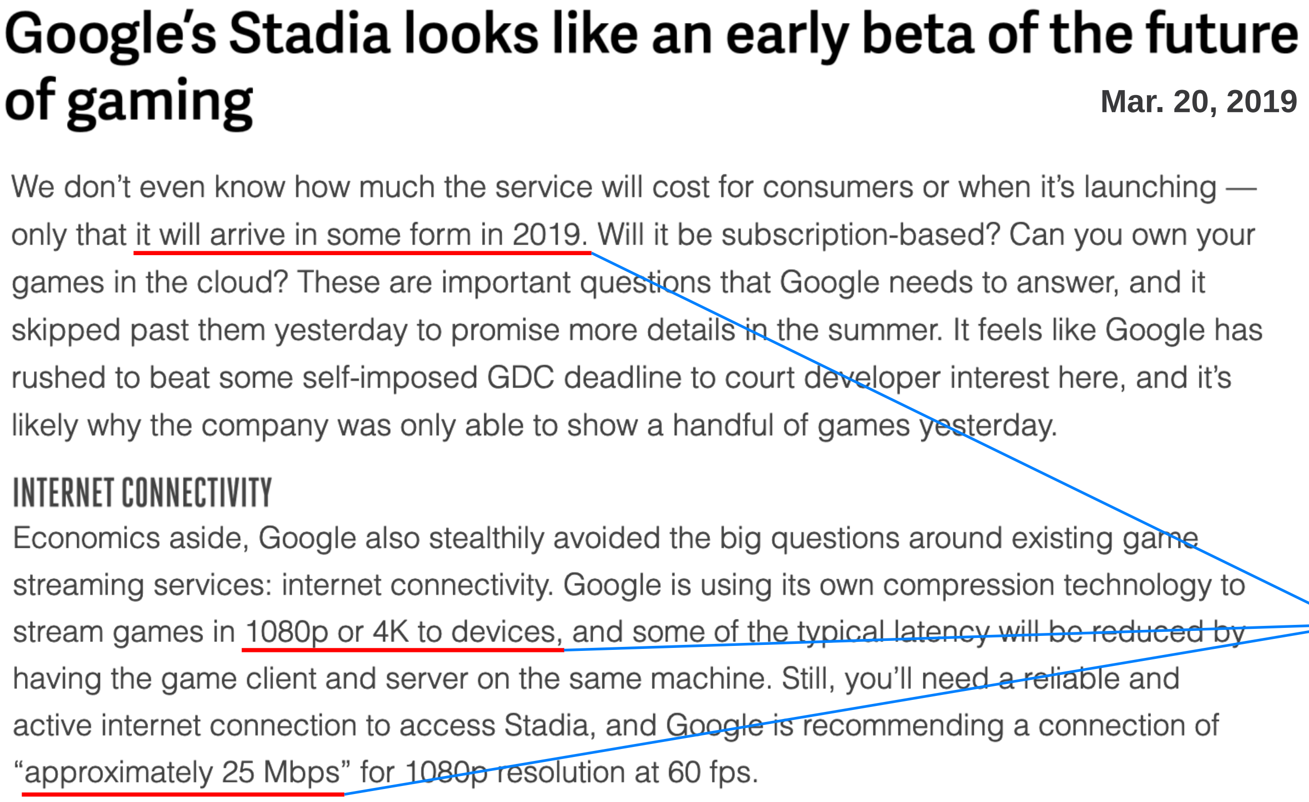
Use Case : Cloud Gaming

- Google's Stadia is game with UHD quality based on Cloud



Google's Stadia looks like an early beta of the future of gaming

Mar. 20, 2019

We don't even know how much the service will cost for consumers or when it's launching — only that it will arrive in some form in 2019. Will it be subscription-based? Can you own your games in the cloud? These are important questions that Google needs to answer, and it skipped past them yesterday to promise more details in the summer. It feels like Google has rushed to beat some self-imposed GDC deadline to court developer interest here, and it's likely why the company was only able to show a handful of games yesterday.

INTERNET CONNECTIVITY

Economics aside, Google also stealthily avoided the big questions around existing game streaming services: internet connectivity. Google is using its own compression technology to stream games in 1080p or 4K to devices, and some of the typical latency will be reduced by having the game client and server on the same machine. Still, you'll need a reliable and active internet connection to access Stadia, and Google is recommending a connection of "approximately 25 Mbps" for 1080p resolution at 60 fps.

UHD Video Games from Cloud within 2019 → 25 Mbps / 10 msec

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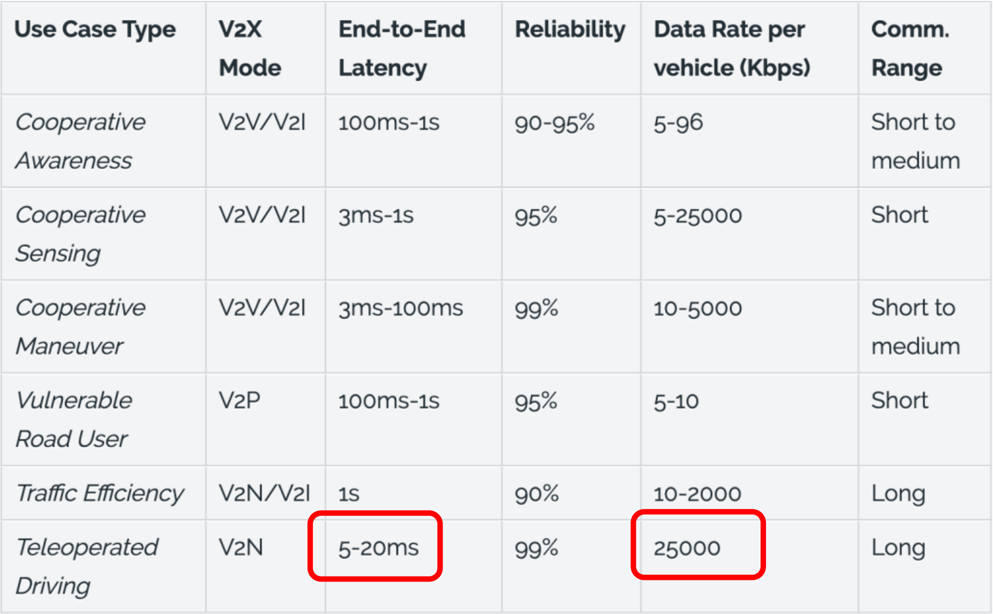
Use Case : Autonomous Car

- Google “Waymo One” is the 1st commercial autonomous vehicle in Dec 5th, 2018

Commercial launch for Self-driving taxi in Phoenix suburbs on Dec 5th



Use Case Type	V2X Mode	End-to-End Latency	Reliability	Data Rate per vehicle (Kbps)	Comm. Range
Cooperative Awareness	V2V/V2I	100ms-1s	90-95%	5-96	Short to medium
Cooperative Sensing	V2V/V2I	3ms-1s	95%	5-25000	Short
Cooperative Maneuver	V2V/V2I	3ms-100ms	99%	10-5000	Short to medium
Vulnerable Road User	V2P	100ms-1s	95%	5-10	Short
Traffic Efficiency	V2N/V2I	1s	90%	10-2000	Long
Teleoperated Driving	V2N	5-20ms	99%	25000	Long

Source : 3GPP RT 22.186 V15.0.0 : Service requirements for enhanced V2X scenarios

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SP Transport Future Requirement : Infra Readiness for Cloud Games, UHD Video, VR/AR, Autonomous Vehicle

☐ **Fixed Broadband**

Fixed	Ave. Download (Mbps)	Ave. Upload (Mbps)	Ave. Latency (msec)
Indonesia	9.4	6.3	33

☐ **4G Mobile Broadband**

Mobile	Ave. Download (Mbps)	Ave. Upload (Mbps)	Ave. Latency (msec)
Indonesia	14.4	6.7	41.81

Min. Over 25 Mbps

Less than 10 msec

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Source : Broadband speedchecker / Open Signal

Transformation to SD Transport Network

- Build in 5G and Video Transport capabilities into existing IP Transport Network
  - **Segment Routing**
  - **Network Slicing**
  - **EVPN L2&L3 Service**

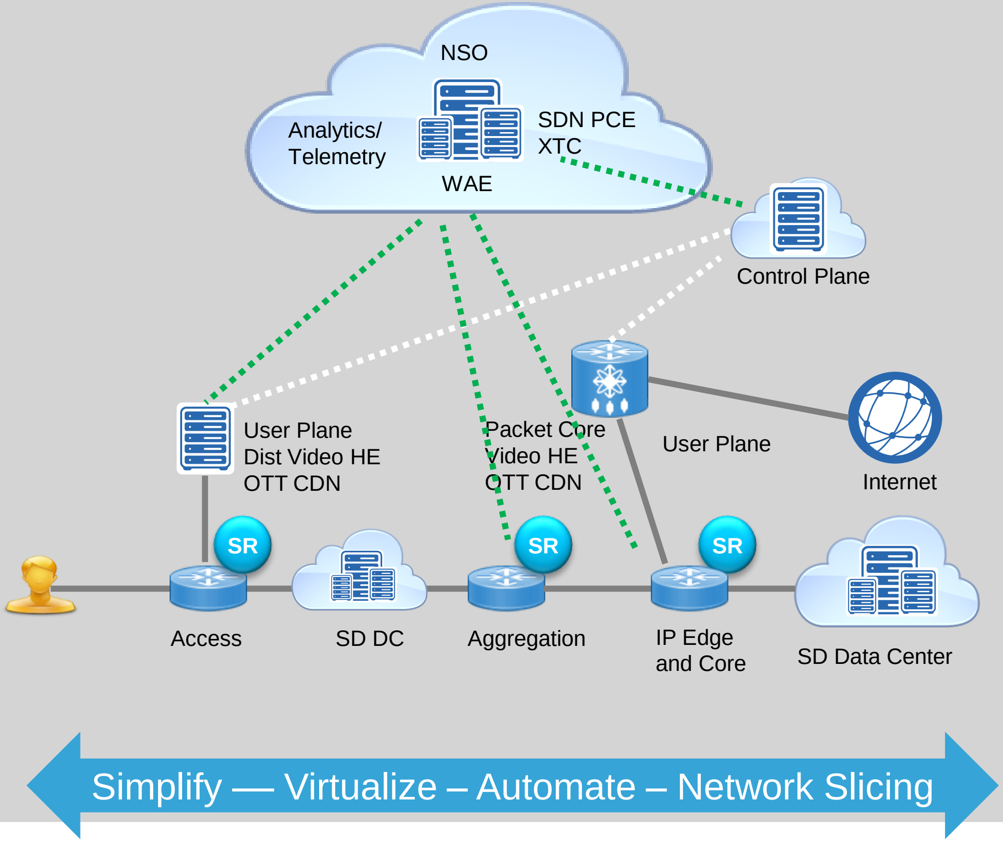
Transport Transformation

Service Transformation

- Evolve traditional service core to virtual (or hybrid) centralized Video HE/OTT to dist Video HE/OTT
  - CUPS / Distributed Video HE / OTT / CDN
  - Distributed Functions
  - Edge Compute
- Automate and Orchestrate

SDN Automation

  - **NSO Orchestrator**
  - **WAE Analytic (WAN Automation Engine)**
  - **SDN SR PCE**
  - **Telemetry**
- SD DC / Telco DC Transformation
  - Spine – Leaf Architecture
  - Cloud Native Service
  - Virtualization Service



Simplify — Virtualize – Automate – Network Slicing

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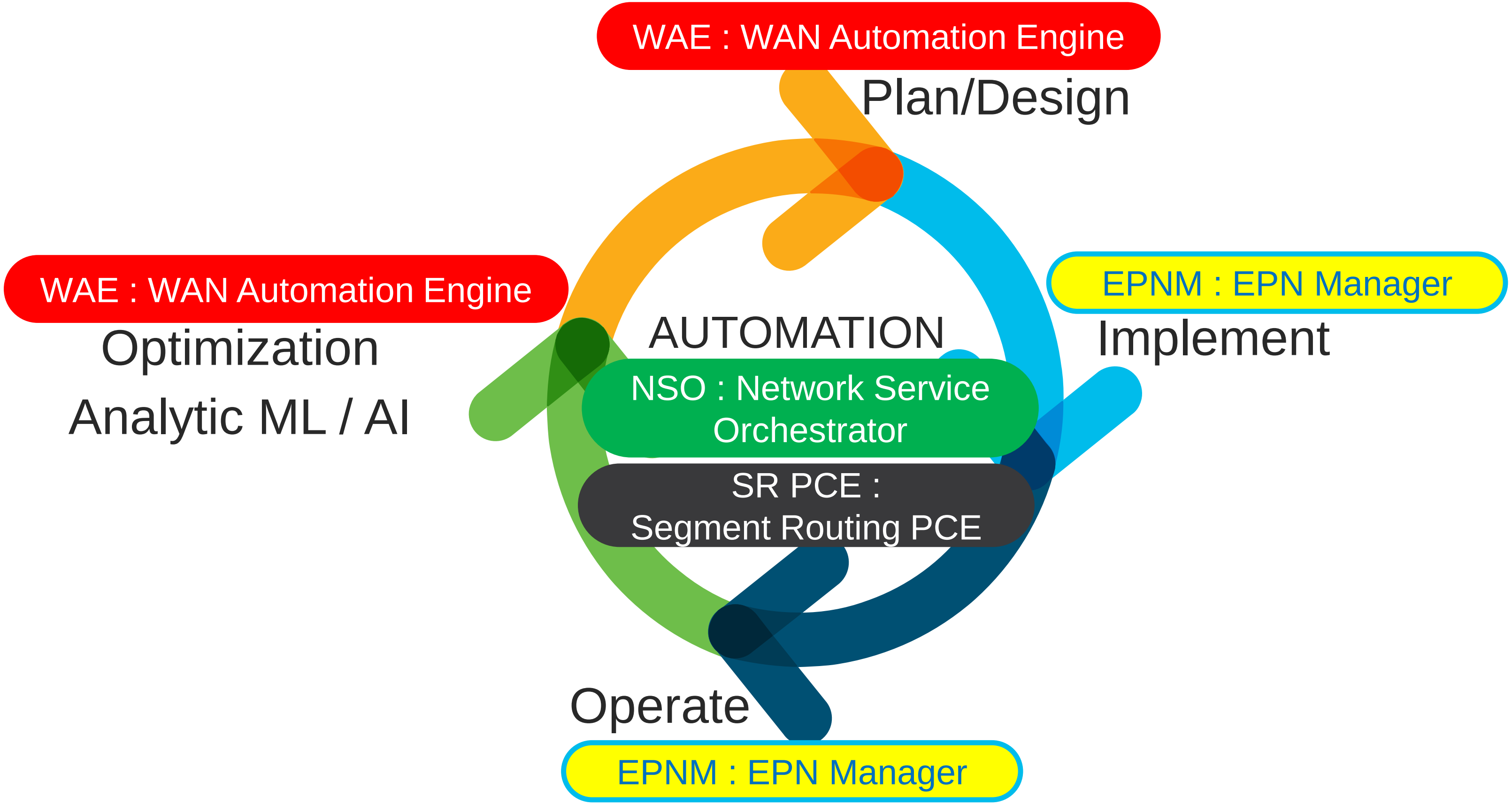
SDN Automation in Network Lifecycle



WAE : WAN Automation Engine

Plan/Design

EPNM : EPN Manager

Implement

WAE : WAN Automation Engine

Optimization

Analytic ML / AI

AUTOMATION

NSO : Network Service Orchestrator

SR PCE : Segment Routing PCE

Operate

EPNM : EPN Manager

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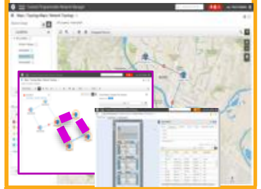
SDN Automation in Network Lifecycle

EPNM

Evolved Programmable Network Manager

Detect
Correlate
Isolate



Dynamic Inventory

”Operate” service, network & device resources as the single point of truth for all operations

NMS ASSURANCE

WAE

WAN Automation Engine

Optimize

BW & Topology Optimization

Traffic planning, design & optimization within the network

ANALYTIC SIMULATION

SR PCE

XR Transport Controller

Path Computation Element

Model Driven Orchestration

Real Time Path Compute and Topology

SDN SR PATH COMPUTATION

NSO

Network Service Orchestrator

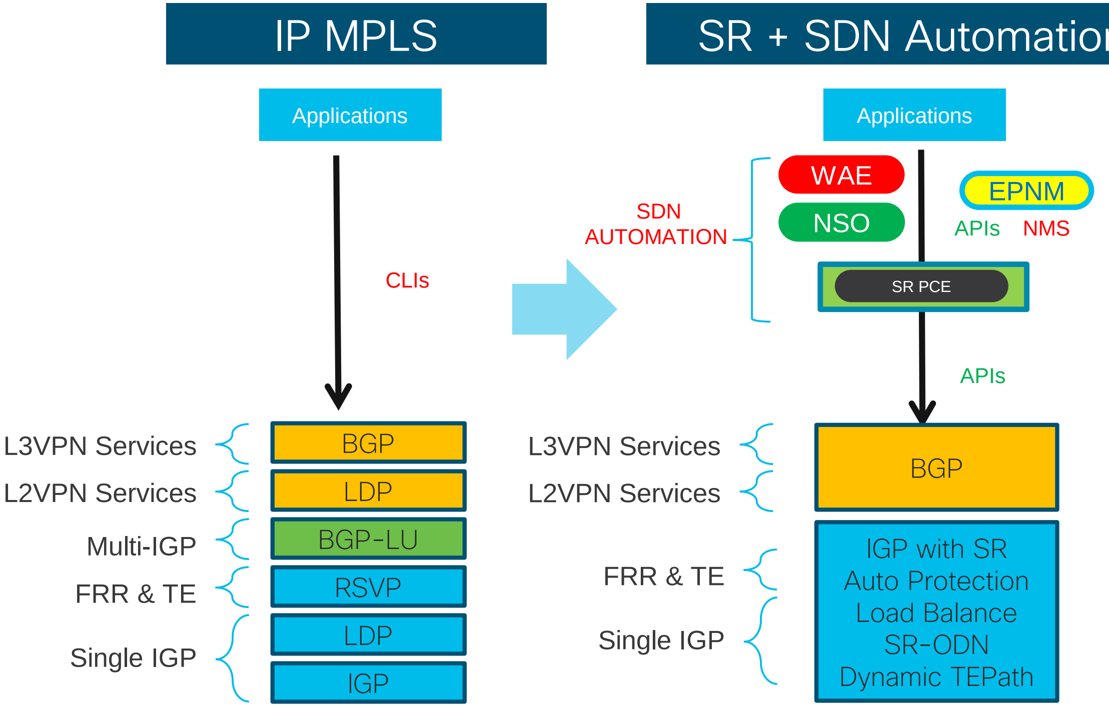
Deploy

Model Driven Orchestration

Implement Agile Service Orchestration for Across WAN, DC, NFVI

ORCHESTRATOR

IP MPLS Evolution to Segment Routing + SDN Automation



IP MPLS

Applications

CLIs

L3VPN Services – BGP

L2VPN Services – LDP

Multi-IGP – BGP-LU

FRR & TE – RSVP

Single IGP – LDP, IGP

SR + SDN Automation

Applications

SDN AUTOMATION – WAE, NSO, SR PCE

EPNM

APIs NMS

APIs

L3VPN Services, L2VPN Services – BGP

FRR & TE, Single IGP – IGP with SR, Auto Protection, Load Balance, SR-ODN, Dynamic TEPath

Benefit

- End to End Visibility & Analysis
- Simulation & Prediction
- Network Service Optimization
- Cust SLA On-Demand Automation

- > 50% Simplification Protocol
- Simplied SLA Path with SR-ODN
- Automated sub-50ms Protection
- Automated Microloop Avoidance
- Automated Load Balance
- Automated Traffic Eng & Steered

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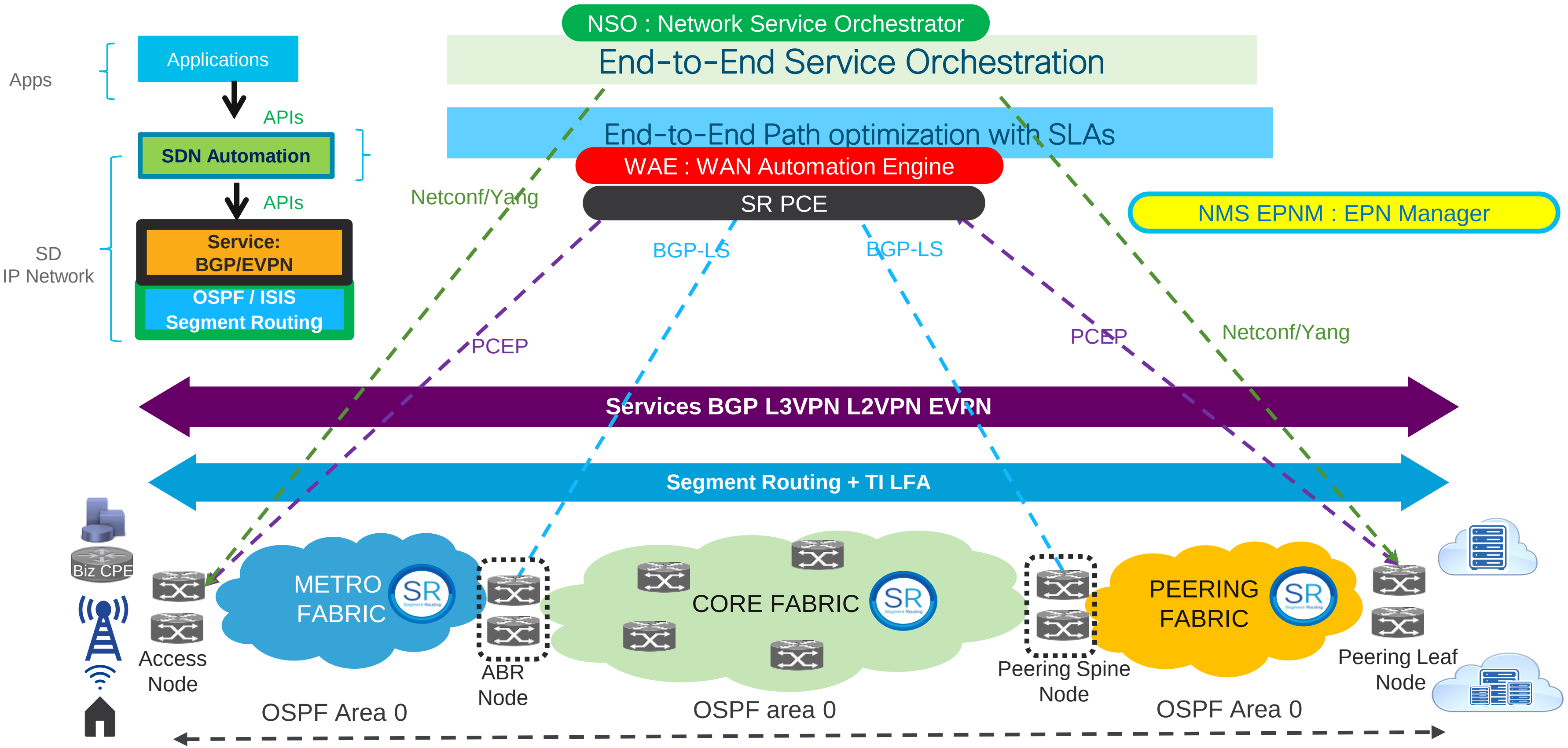
SD Transport Network Architecture



Apps

Applications

APIs

SDN Automation

APIs

SD
IP Network

**Service:
BGP/EVPN**

**OSPF / ISIS
Segment Routing**

NSO : Network Service Orchestrator

End-to-End Service Orchestration

End-to-End Path optimization with SLAs

WAE : WAN Automation Engine

SR PCE

NMS EPNM : EPN Manager

Netconf/Yang

BGP-LS

BGP-LS

PCEP

PCEP

Netconf/Yang

Services BGP L3VPN L2VPN EVPN

Segment Routing + TI LFA

Biz CPE

Access
Node

METRO
FABRIC

ABR
Node

CORE FABRIC

Peering Spine
Node

PEERING
FABRIC

Peering Leaf
Node

OSPF Area 0

OSPF area 0

OSPF Area 0

Multidomain IGP – Seamless IP MPLS – Unified MPLS

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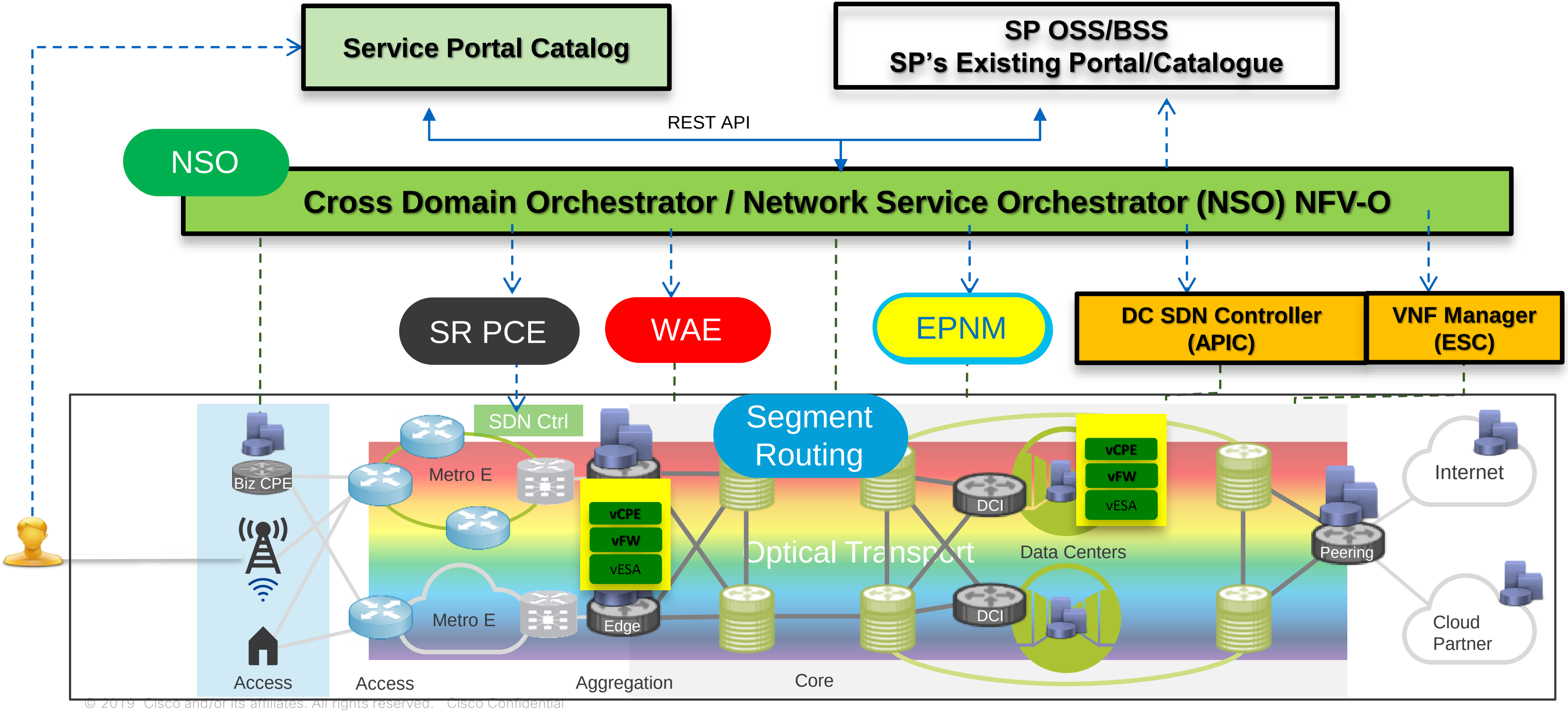
SDN Automation Framework



Service Portal Catalog

SP OSS/BSS
SP's Existing Portal/Catalogue

REST API

NSO

Cross Domain Orchestrator / Network Service Orchestrator (NSO) NFV-O

SR PCE

WAE

EPNM

DC SDN Controller (APIC)

VNF Manager (ESC)

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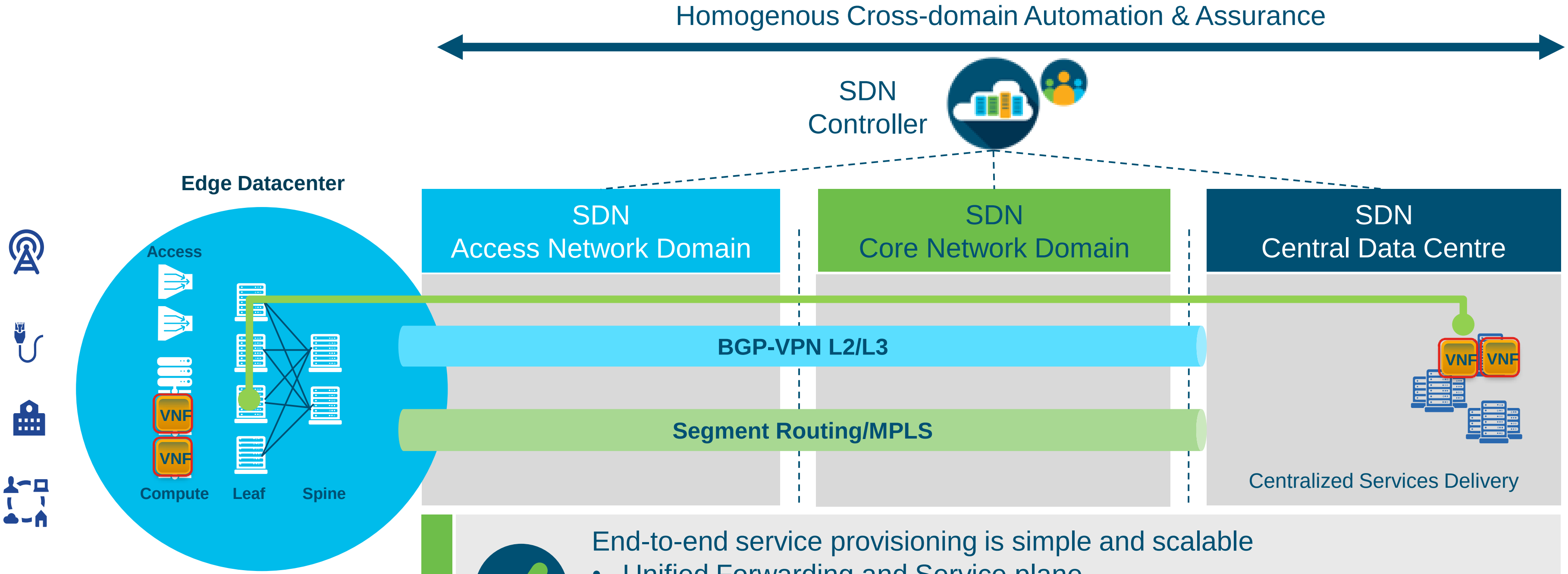
Cisco 5G Converged SDN Transport

5G Services	Enhanced Mobile Broadband (eMBB)	Massive Machine Types Communications (mMTC)	Ultra-Reliable and Low Latency Communications (URLLC)
Service Orchestration & Programmability	SDN FRAMEWORK : (NSO Network Service Orchestrator) (WAE Wan Automation Engine) (SR-PCE Segment Routing PCE)		
Service	Ethernet VPN (EVPN) and L3VPN		
Transport	Programmable SR Fabric Segment Routing (SR MPLS / SRv6) & SR PM Clocking (1588/SyncE – Phase and Frequency)		

Cisco 5G Converged SDN Transport



End-to-end service provisioning is simple and scalable

- Unified Forwarding and Service plane
- Multiple network domains under same management teams
- Automated operations

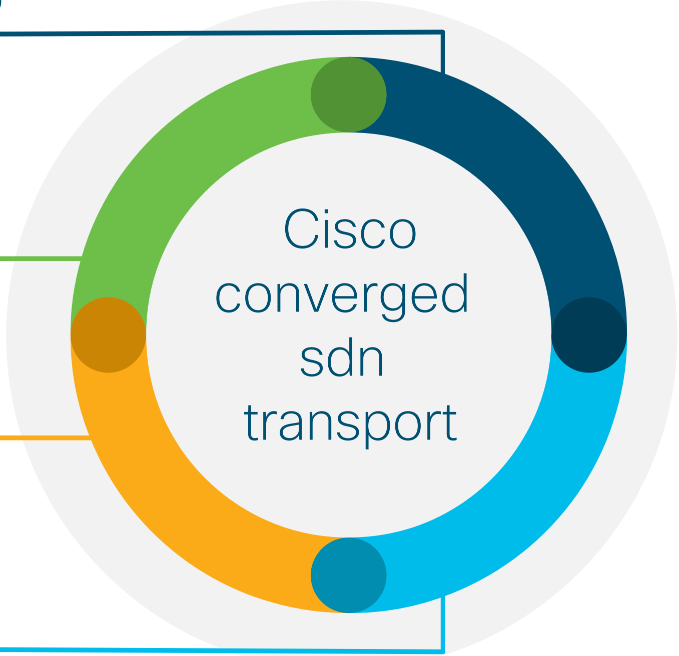
5G Transport Foundations “Done Right”

high-performance, 5G-ready portfolio

trusted infrastructure

cross domain automation

software-driven simplification



Cisco converged sdn transport

ACG Research https://www.acgcc.com/tco-benefits-ofconverged5g-ready-iptransport/

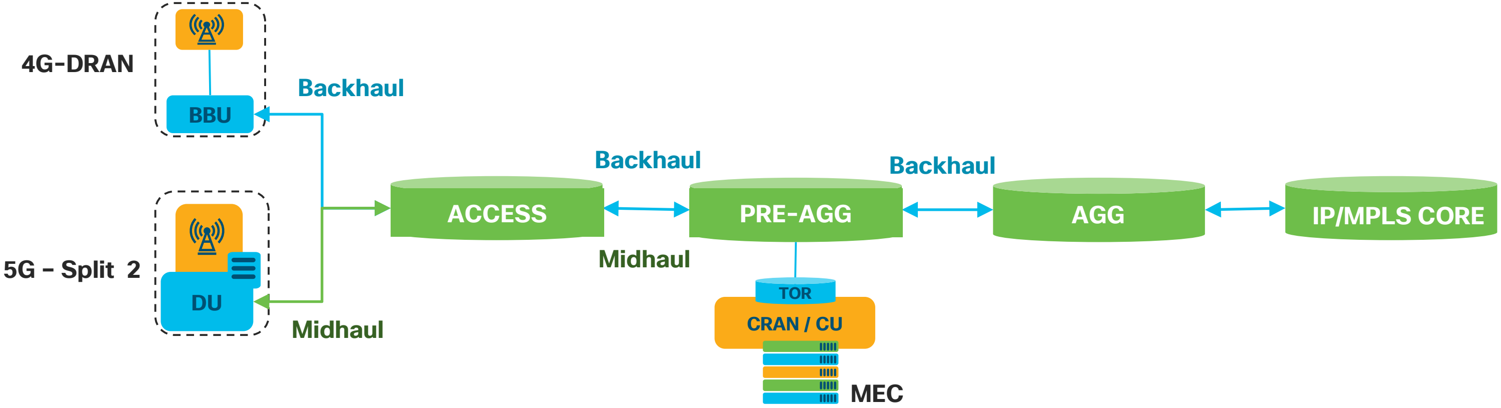
Lowering TCO by 62%

60% improved capital efficiency

66% better OPEX utilization

81% faster time-to-service

Cisco 5G Transport Platforms



4G-DRAN

BBU

Backhaul

5G – Split 2

DU

Midhaul

Backhaul

Midhaul

Backhaul

ACCESS

PRE-AGG

AGG

IP/MPLS CORE

TOR

CRAN / CU

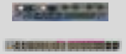
MEC

C-RAN Fabric	ACCESS	PRE-AGG	AGG	IP Core
• NCS540 Family • NCS550x • NCS560 • ASR9xx	• NCS540 Family • NCS540 • ASR9xx	• NCS540 Family • NCS560 • NCS55A1/A2 • ASR990x	• NCS55xx	• ASR99xx • NCS55xx

Highlights

IOS XR

Dense fixed and modular XR portfolio



Small form factor with low power

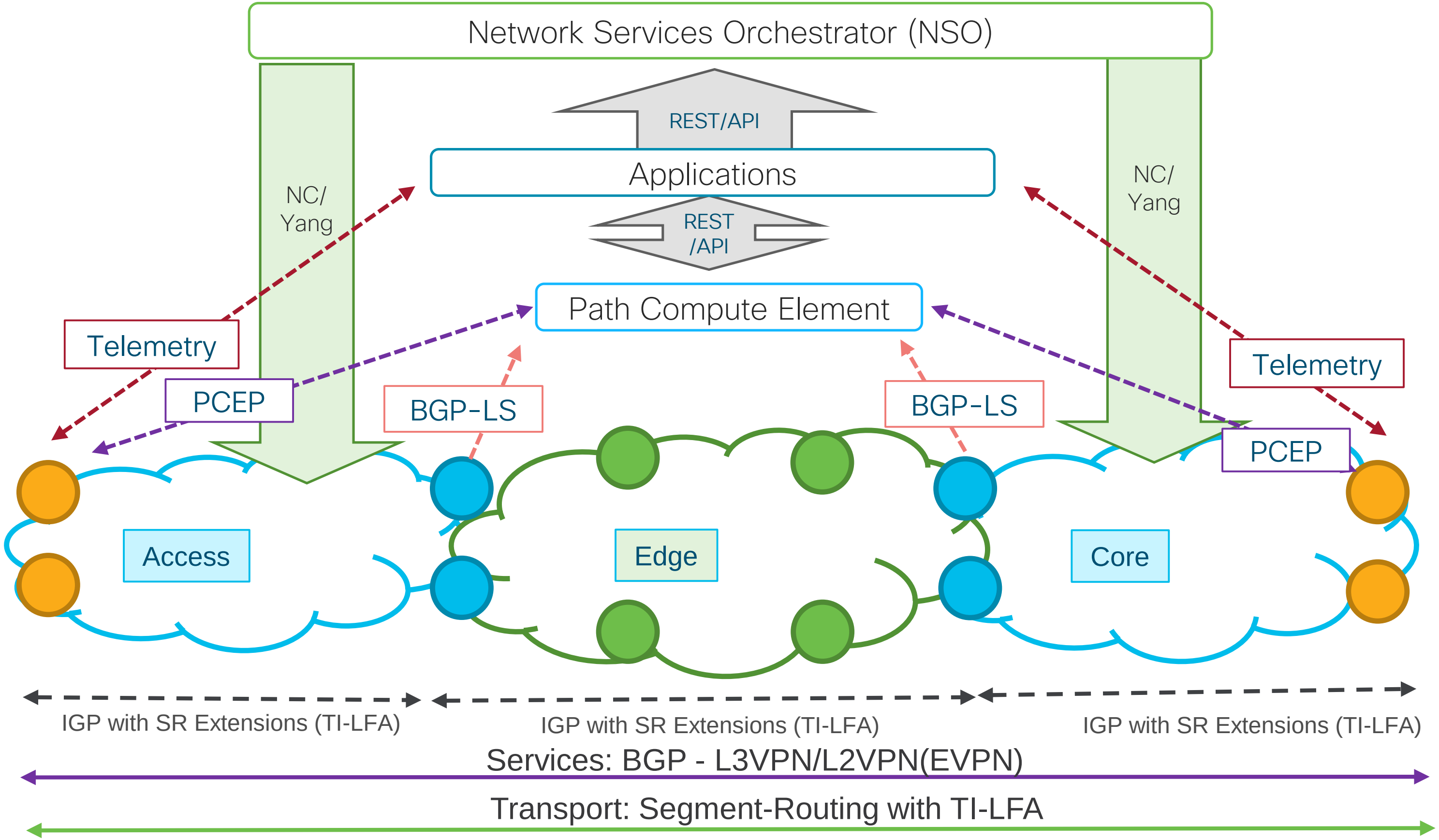
Secure with MACSec encryption

IPoDWDM with CFP2 DCO

Wide range from 300G 3.6T

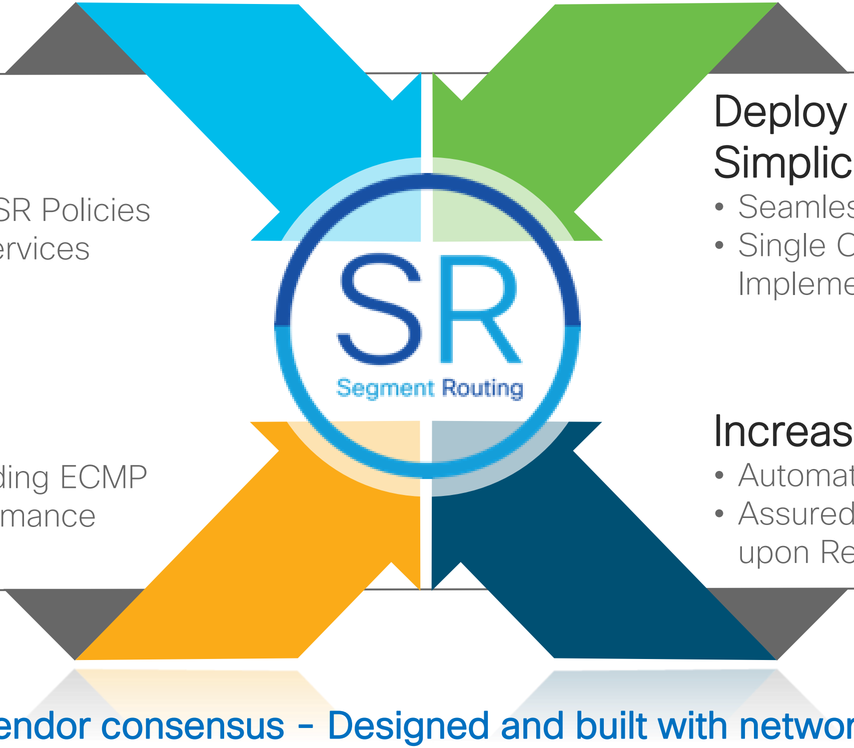
Indoor/outdoor deployments

Network as a Programable Fabric


Network Services Orchestrator (NSO)
REST/API
Applications
NC/ Yang
NC/ Yang
REST /API
Path Compute Element
Telemetry
PCEP
BGP-LS
BGP-LS
Telemetry
PCEP
Access
Edge
Core
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
IGP with SR Extensions (TI-LFA)
Services: BGP - L3VPN/L2VPN(EVPN)
Transport: Segment-Routing with TI-LFA

- App. Driven N/W and Usecases
- Automation
- Data Collection & Analytics
- Device and Services Onboarding
- EVPN Based Services
- Controller Based Forwarding
- Segment Routing Transport

Segment Routing : Value Proposition



Create New Revenue Streams

- Differentiate Services with SR Policies
- Intent-Based Value-Add Services

Deploy with Ease Simplicity

- Seamless Brownfield Integration
- Single Control for Inter Domain Implementations

Monitor Health

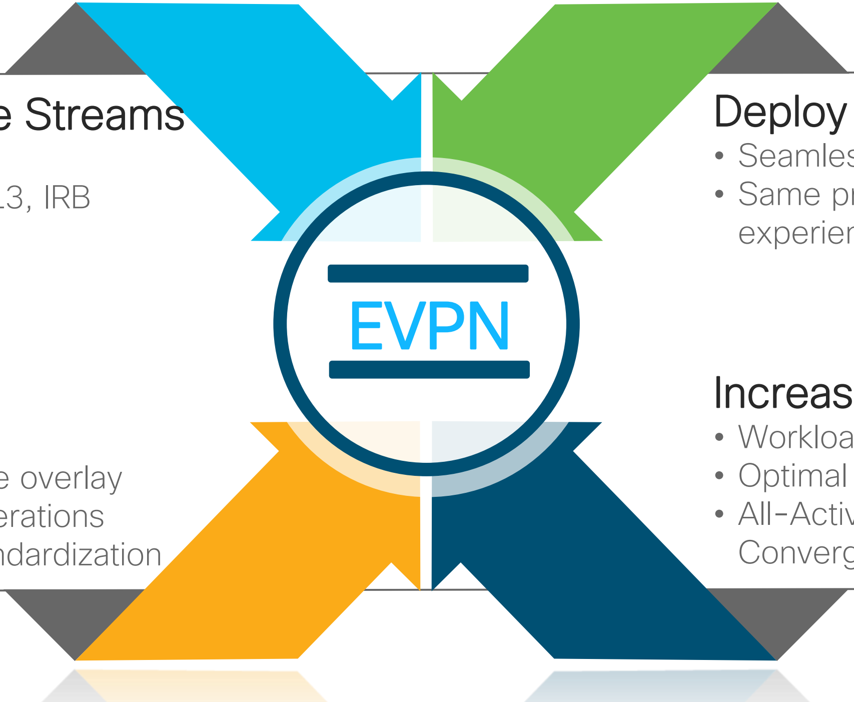
- Data Path Validation Including ECMP
- Real Time Per-Link Performance Monitoring with Telemetry

Increase Availability

- Automated 50ms Protection
- Assured Loop-free Convergence upon Recovery

Multi-vendor consensus - Designed and built with network operators

EVPN : Value Proposition



Create New Revenue Streams

- Stateless SFC and NFV
- E-LAN, E-LINE, E-TREE, L3, IRB Services

Deploy with Ease

- Seamless Brownfield Integration
- Same principles and operational experience as IP VPNs

Protect Investments

- Unified Networks on single overlay
- Simplify protocols and operations
- Industry adoption and standardization

Increase Availability

- Workload Mobility
- Optimal forwarding
- All-Active Redundancy with Fast Convergence

Fast, Resilient, Flexible Unified Services

Cisco Segment Routing Underlay

- **Flex-Algorithm**

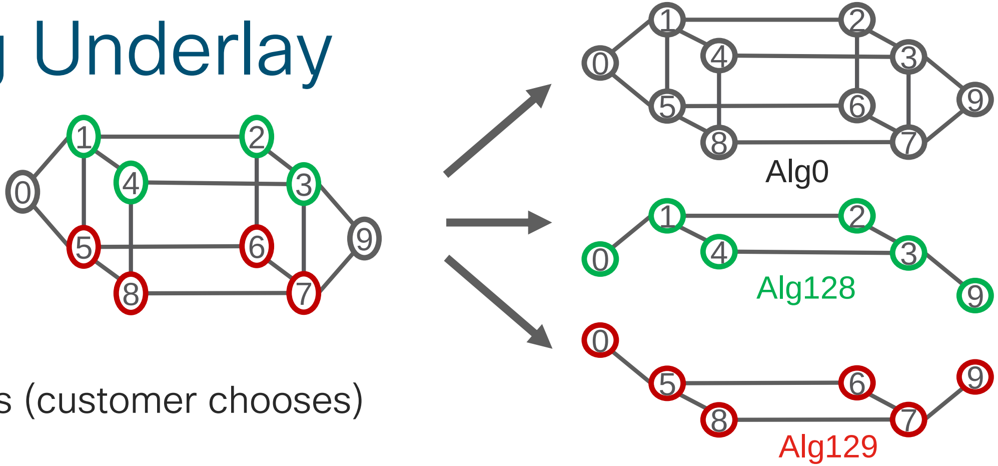
  Builds domain level forwarding tables

  IGP distributes multiple metrics / affinities

  Multi-algorithms operational in network

  SPF, Low Latency, constrained nodes / links (customer chooses)

  TiLFA per algorithm



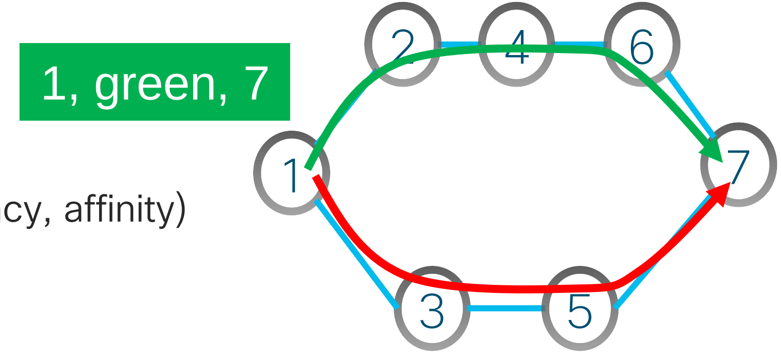
- **SR Policies (or SR-TE)**

  Builds paths between nodes

  Path computation based multiple constraints (b/w, latency, affinity)

  Calculated by head-ends or an SR-PCE

  Multi-domain / disjoint paths require SR-PCE



Example Green: Low latency, Red: IGP path

Cisco SR – Service Aware Traffic Steering

- Traffic Steering

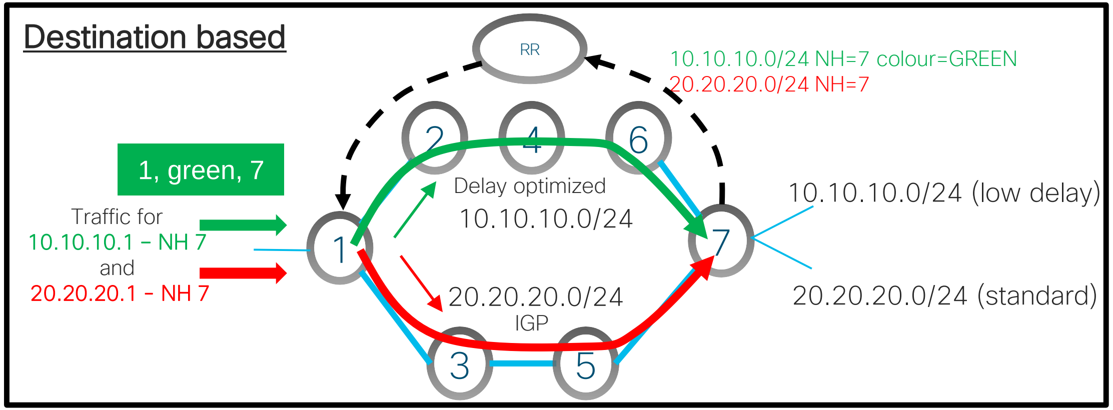
  Mechanism on source router to steer traffic

  By default traffic uses IGP path

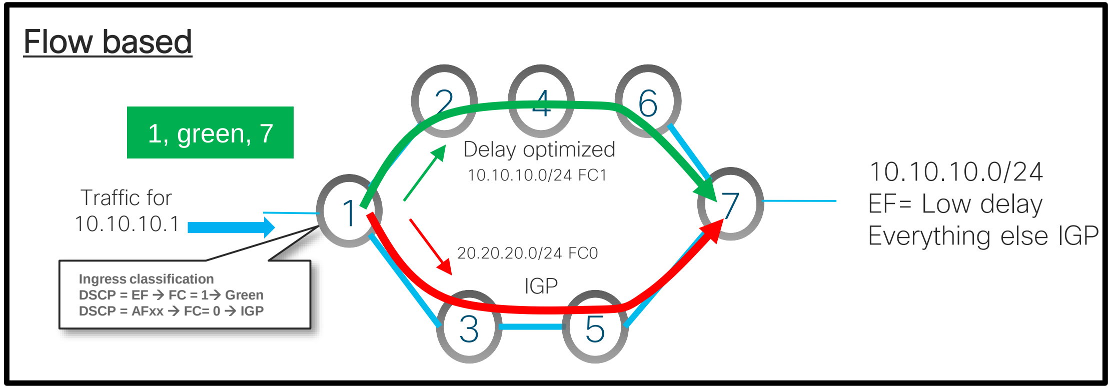
  Can steer traffic into a SR policy or specific Flex-algos

  Destination TS : destination only

  Flow based TS : destination + QoS criteria



Destination based



Flow based

Cisco SR OnDemand NextHop Low Latency Service

Applicability Examples

Extreme Real-time Communications

Tactile Internet

Voice Communications

Fixed / Mobile

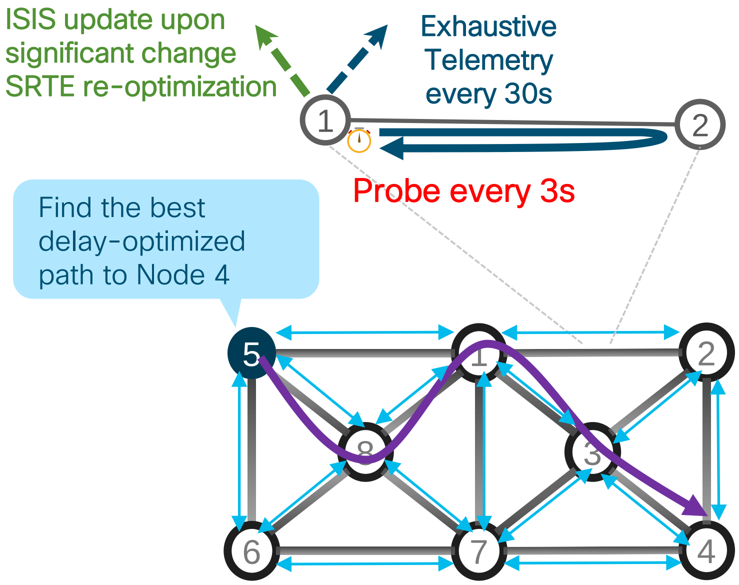
Solution

Compute Low Latency path based on measured link delay/jitter/drop with Performance Monitoring (PM)

Benefits

Simplicity and Automation
Troubleshooting tool
Meet, Maintain and Monitor SLAs at all times

MPLS Performance Monitoring (PM)



ISIS update upon significant change SRTE re-optimization

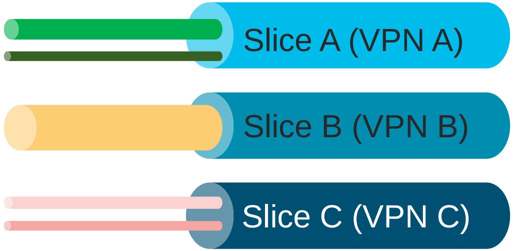
Exhaustive Telemetry every 30s

Probe every 3s

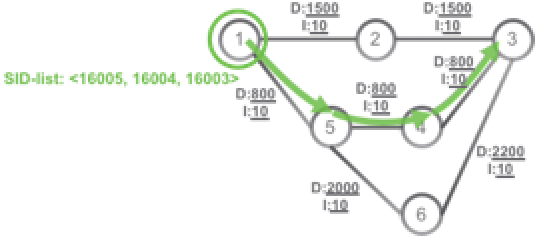
Find the best delay-optimized path to Node 4

MPLS-PM (delay/jitter/loss)

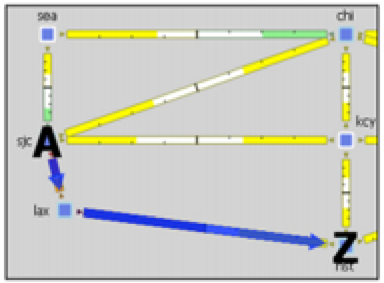
Cisco Soft Network Slicing Transport Solution


Slice A (VPN A)
Slice B (VPN B)
Slice C (VPN C)

Traffic isolation & Differentiated Services



Low Latency Path



Bandwidth Optimization

Network-wide Service Orchestration
(NSO)

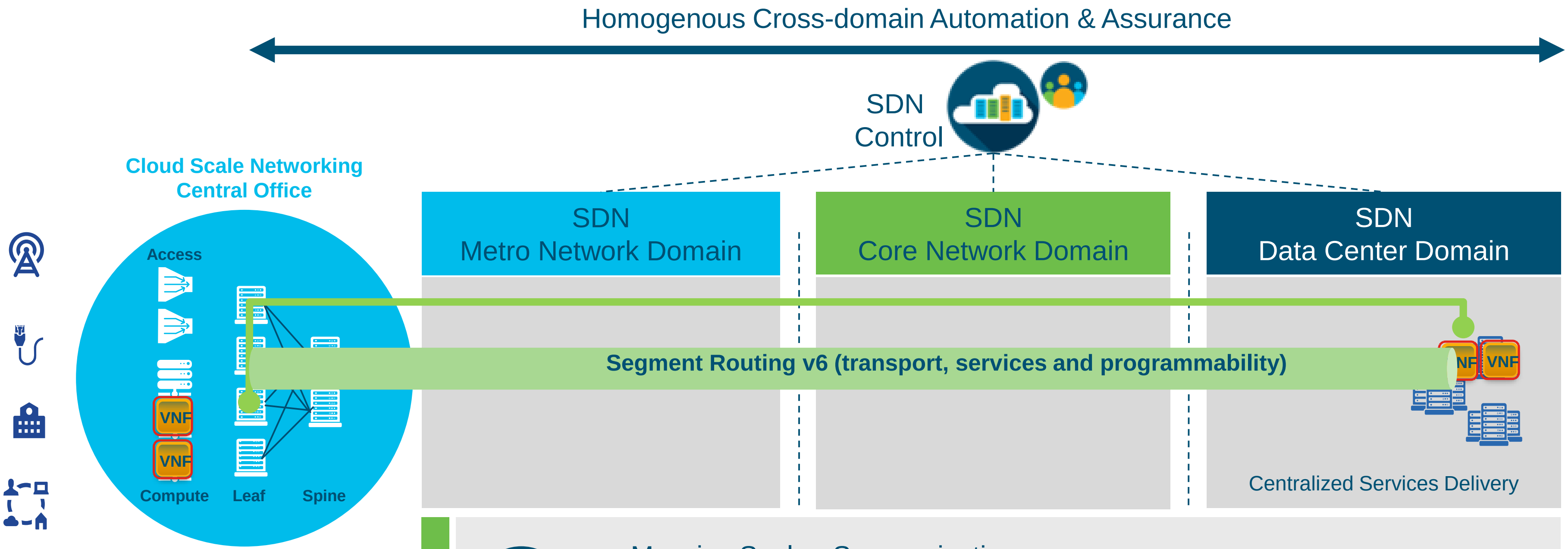
WAE
Network Bandwidth

SR PCE
SR PCE Controller

BGP-LS
Topology and Latency

Segment Routing SR-Policy ODN over L2VPN L3VPN / Flex-Algo
Create Logical Network Topologies

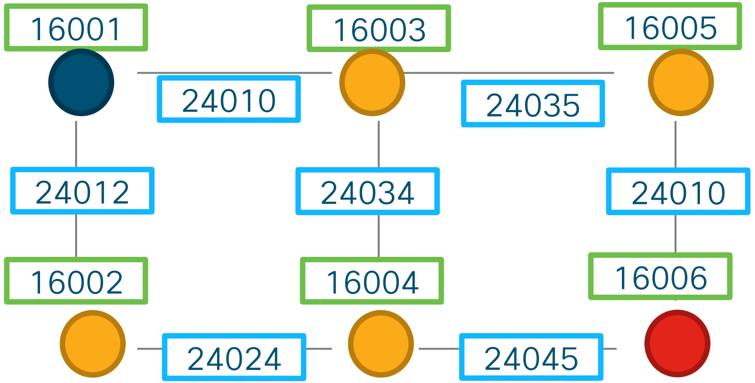
Cisco SRv6



- Massive Scale - Summarization
- Network Programming - Stateless Service chaining
- Network Programmability - SRv6 from the host
- Simplicity
- Network Slicing

Segment Routing Technology Overview

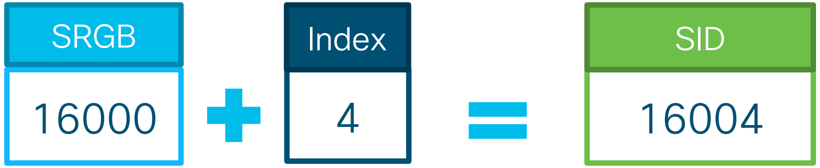
Prefix SID (Node SID)	Adjacency SID
Globally Significant	Locally Significant Unidirectional



Segment = **Instructions** such as
"go to node N using the shortest path"

Segment Routing Technology Overview

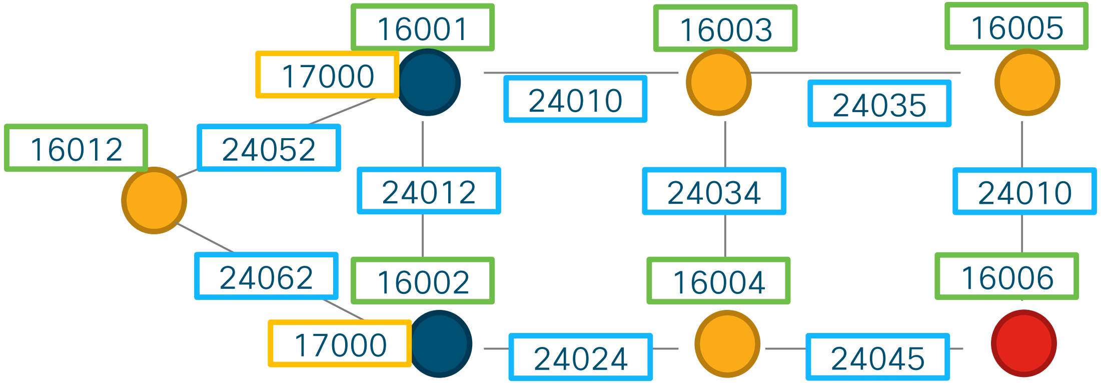
- Configured under IGP Routing Protocol
- Requires: Enabling SR & Configuring Prefix-SID
  - Configure “Absolute Value” or “Index”
- Optional: Configure SR-Global-Block (SRGB).
  - Default 16000 – 23999 (higher in newer versions)
- SRGB & Index advertised using IGP



- Result: No LDP Needed for label distribution

Segment Routing – Technology Overview

Prefix SID	Adjacency SID	Anycast SID
Globally Significant	Locally Significant Unidirectional	Globally Significant



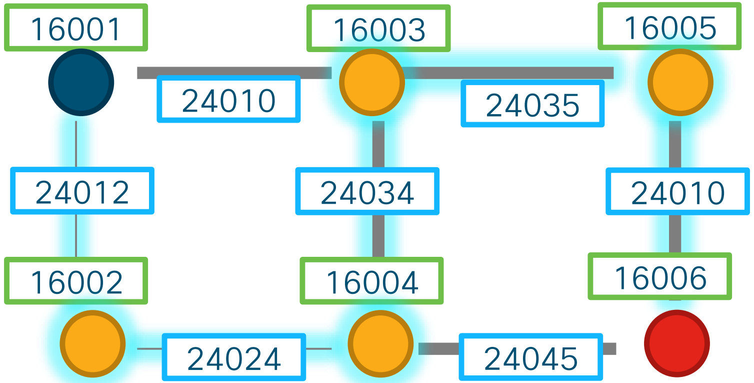
Segment Routing – Programming The Path

SRTE

Go To "RED"

RED = SID-List:
24012
24024
16003
16005
16006

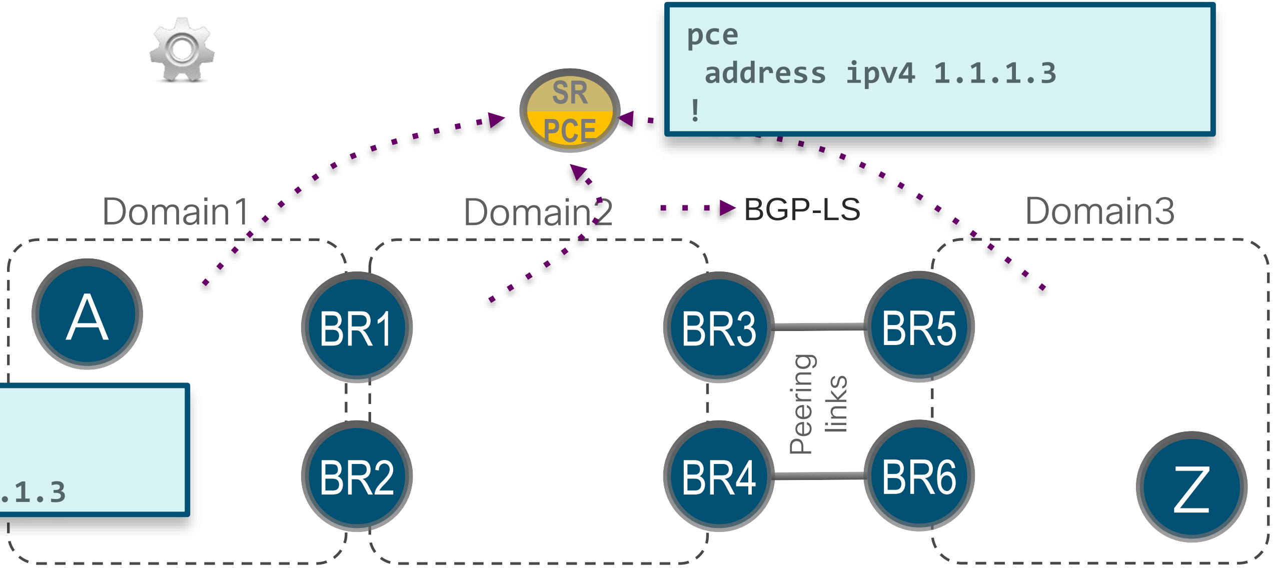
24012; INT="x"



Reached "RED"

SR-PCE

- SR-PCE is an IOS XR multi-domain stateful SR Path Computation Element (PCE)
  - Fundamentally Distributed (RR-like Deployment)



On XTC:

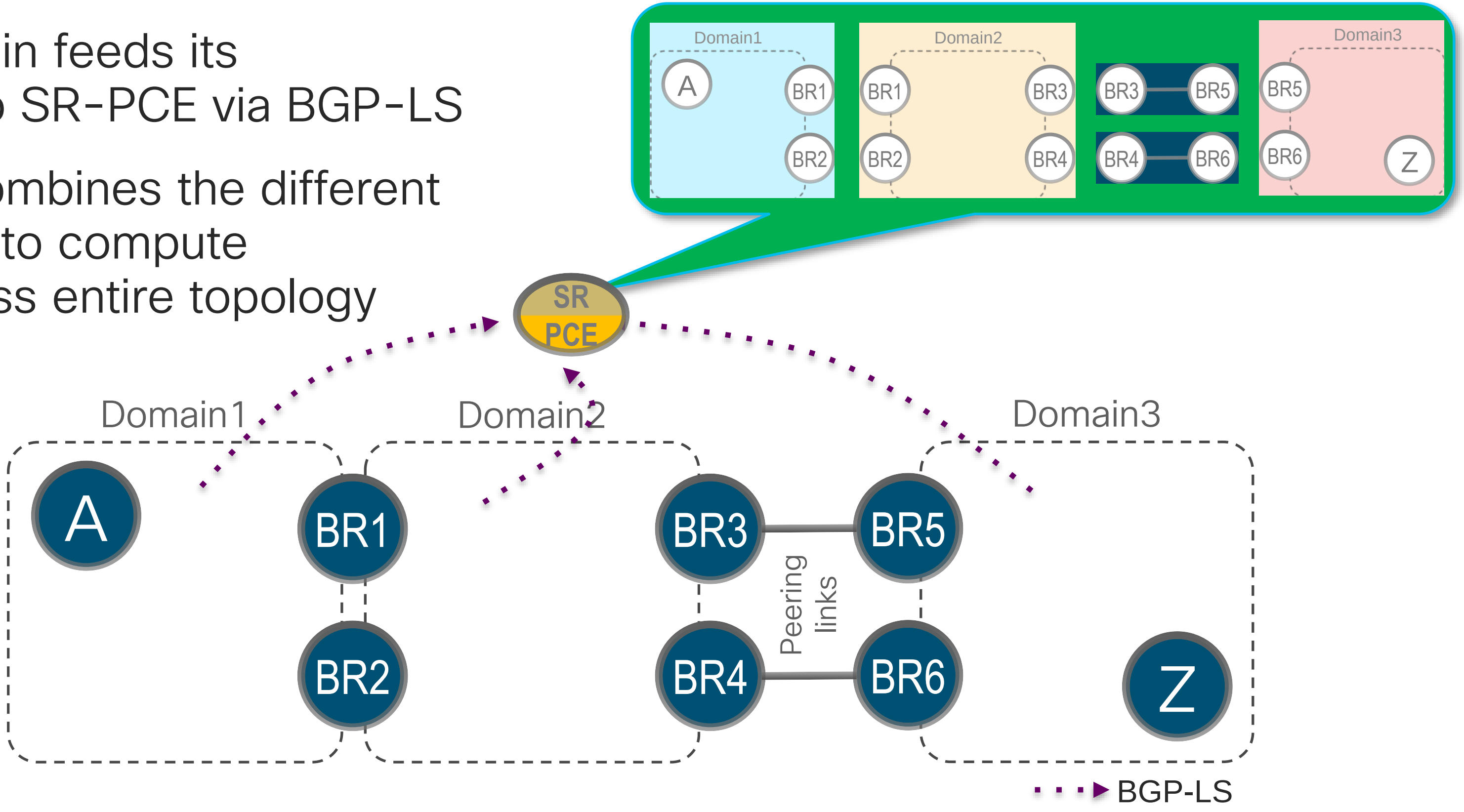
```
pce
 address ipv4 1.1.1.3
!
```

On PE:

```
pcc
  pce
   address ipv4 1.1.1.3
!
```

SR-PCE Receives & Consolidates Multiple Topologies

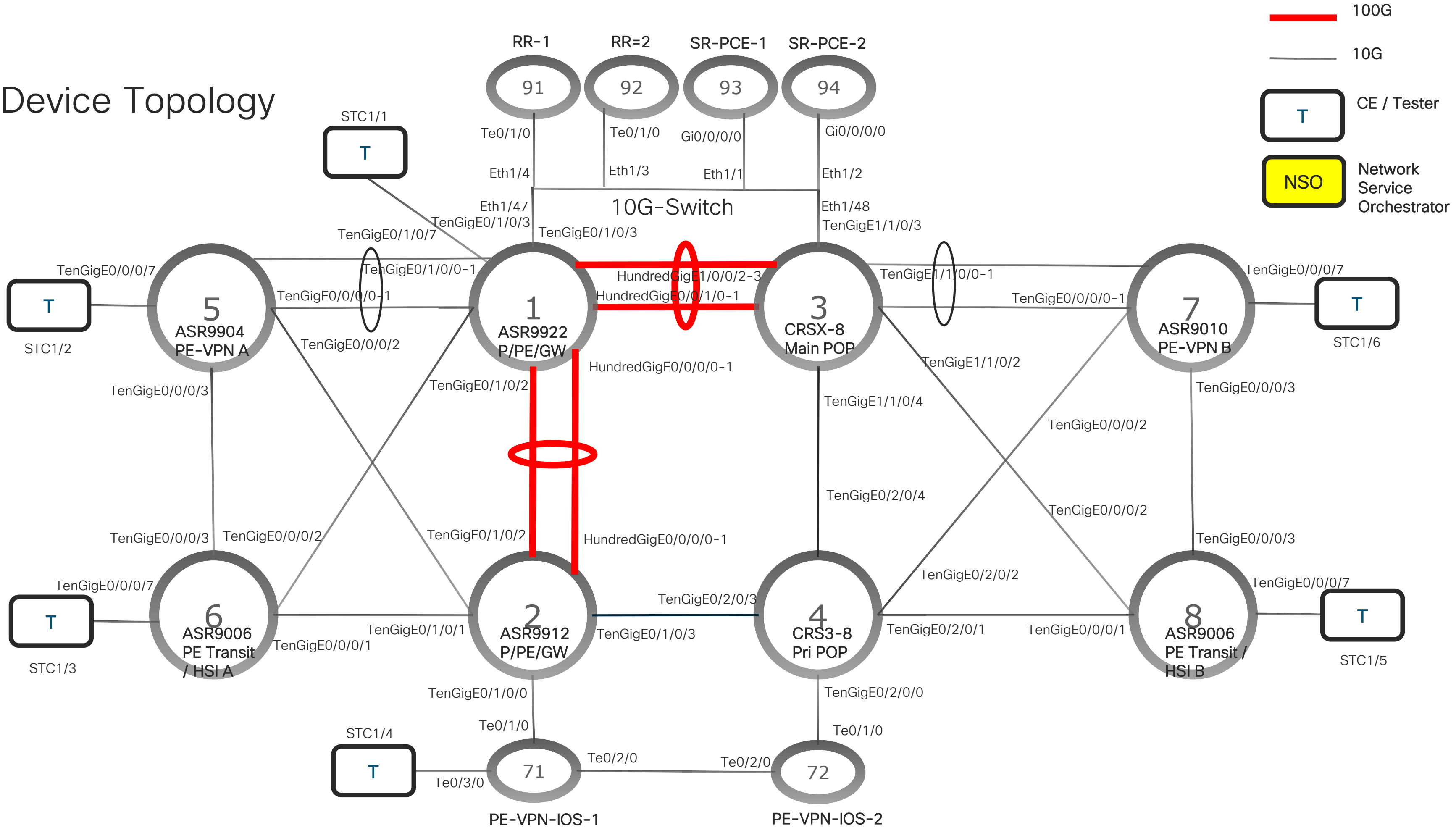
- Each domain feeds its topology to SR-PCE via BGP-LS
- SR-PCE combines the different topologies to compute paths across entire topology



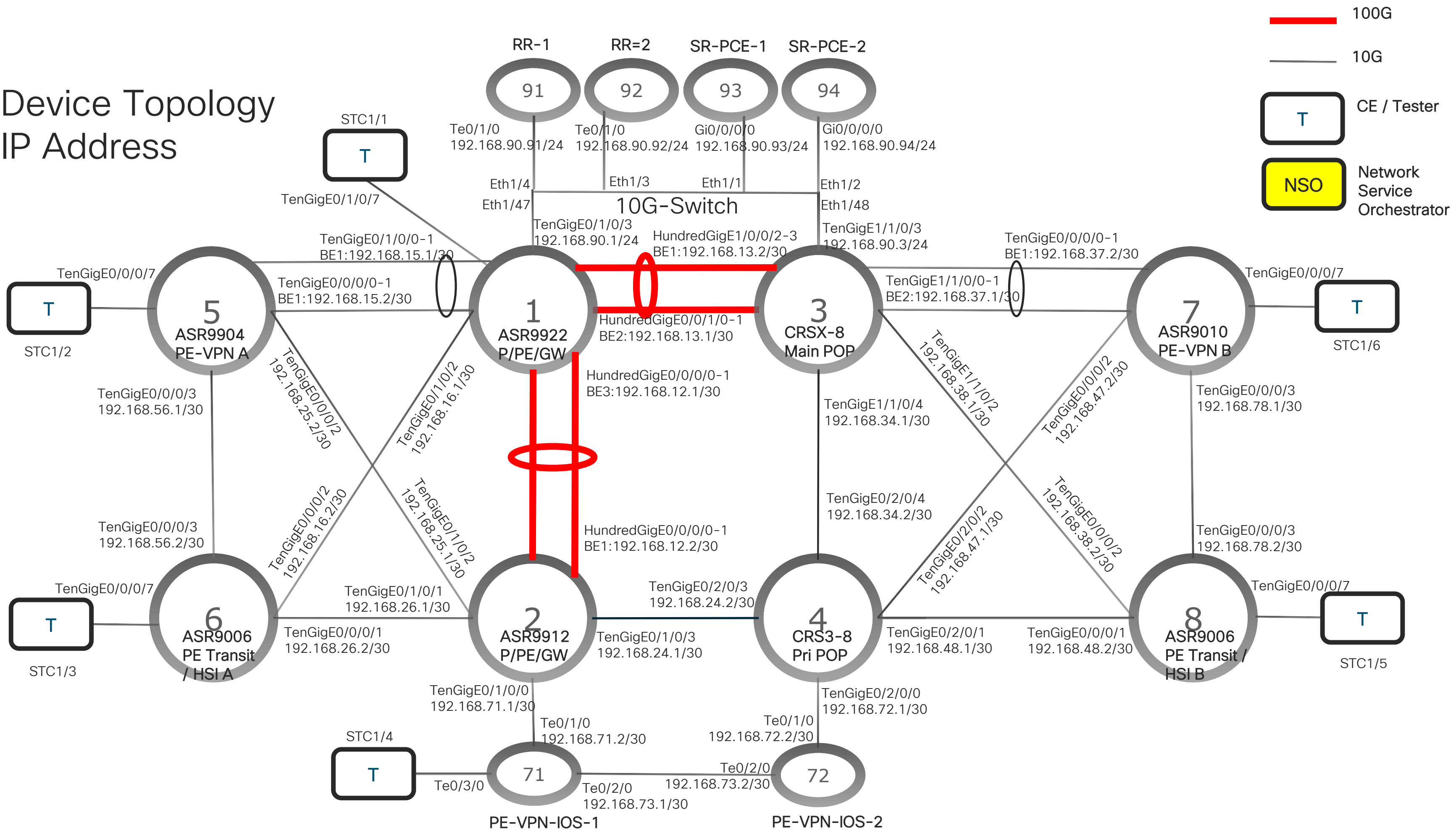
Demo SDN Transport Topology Device List

You make networking **possible**

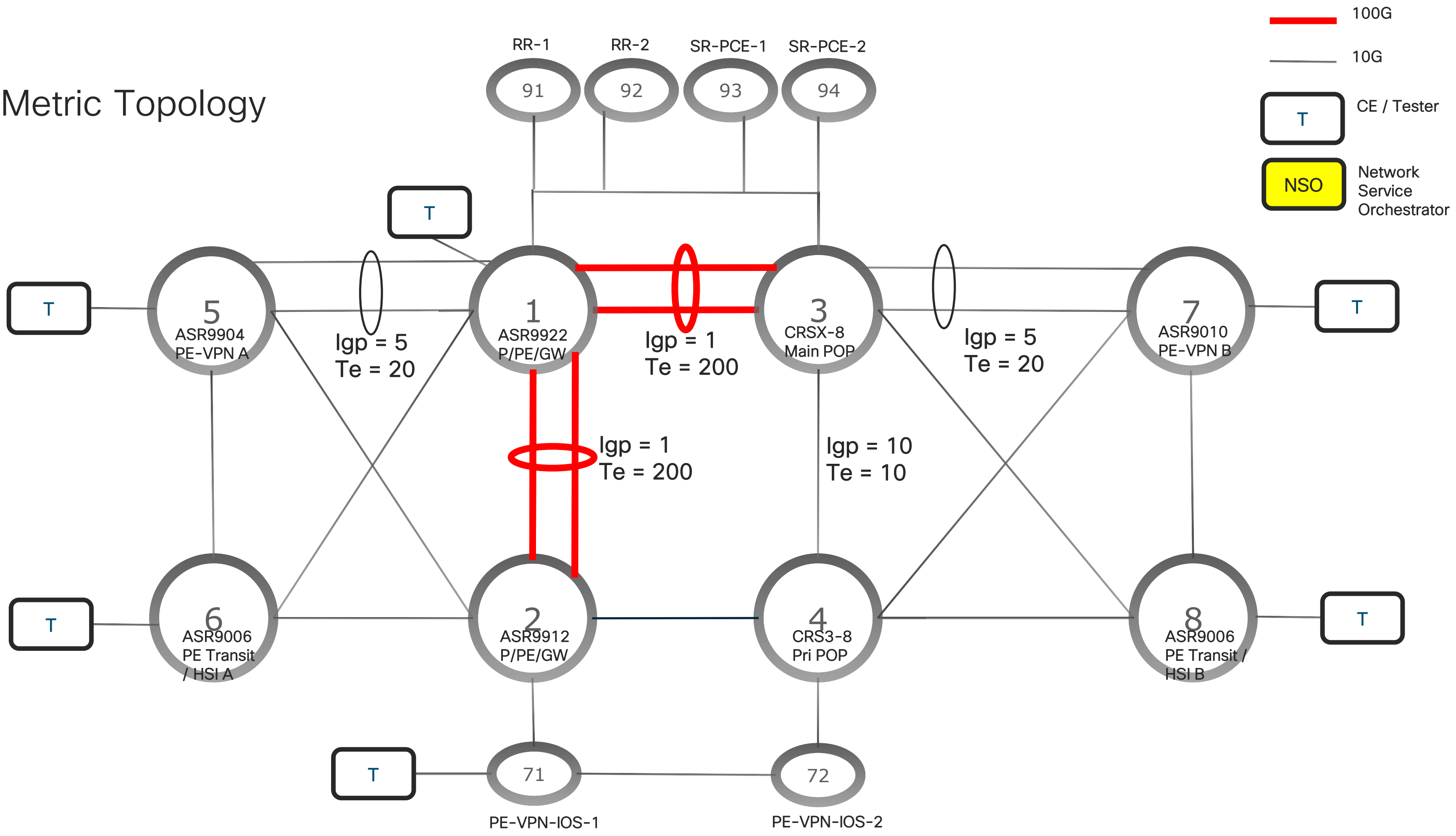
Device Topology



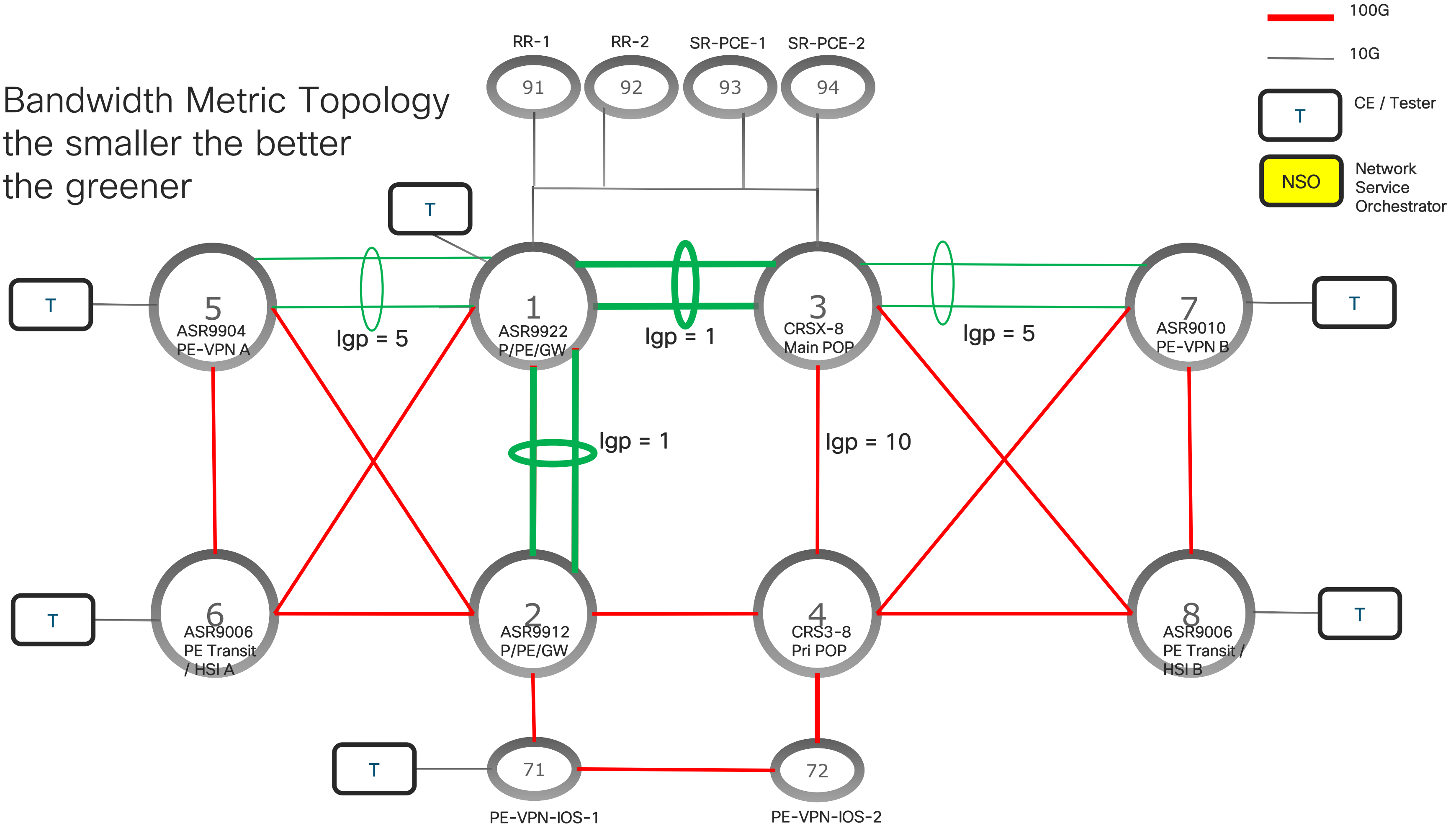
Device Topology
IP Address



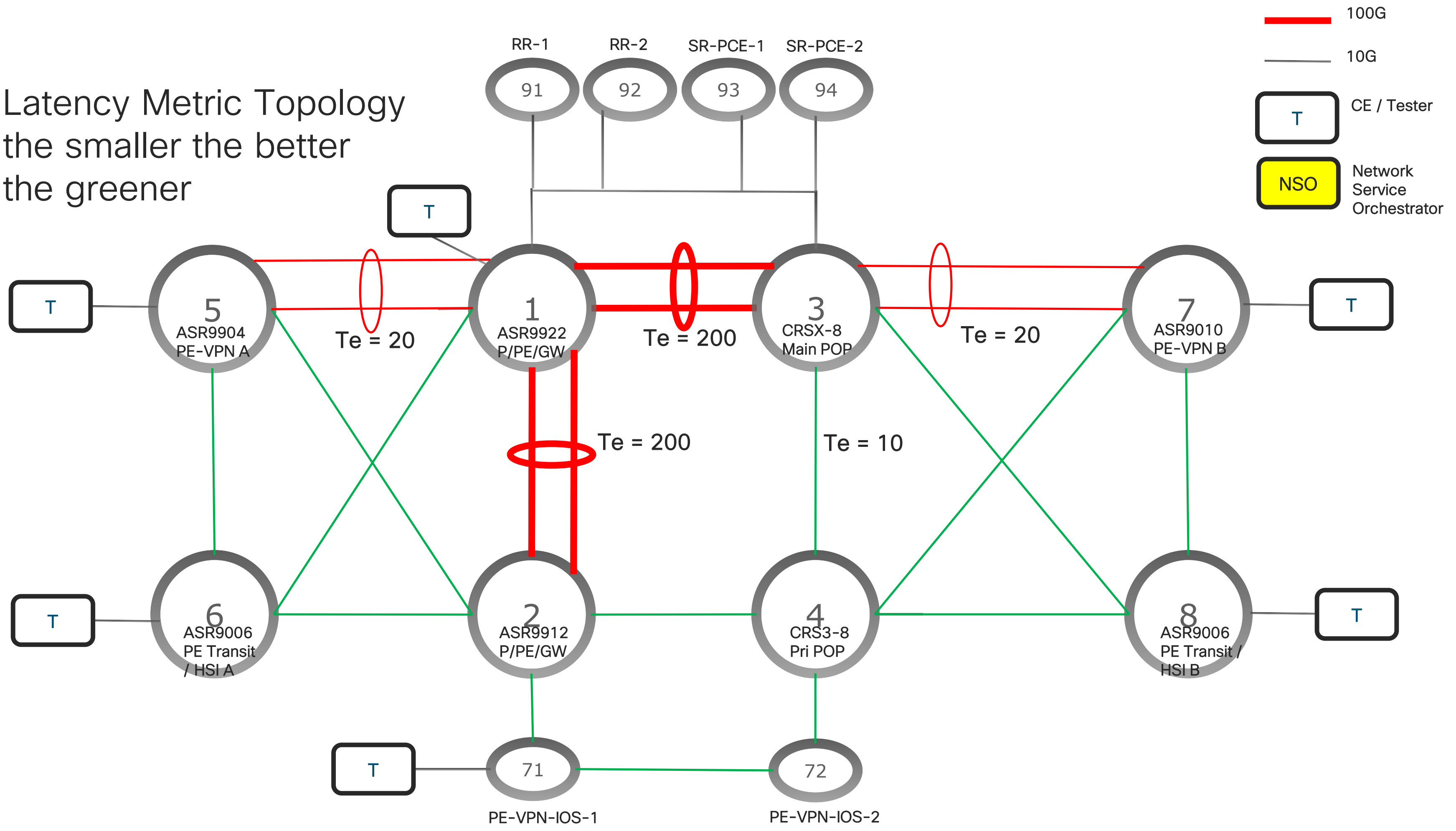
Metric Topology



Bandwidth Metric Topology
the smaller the better
the greener



Latency Metric Topology
the smaller the better
the greener



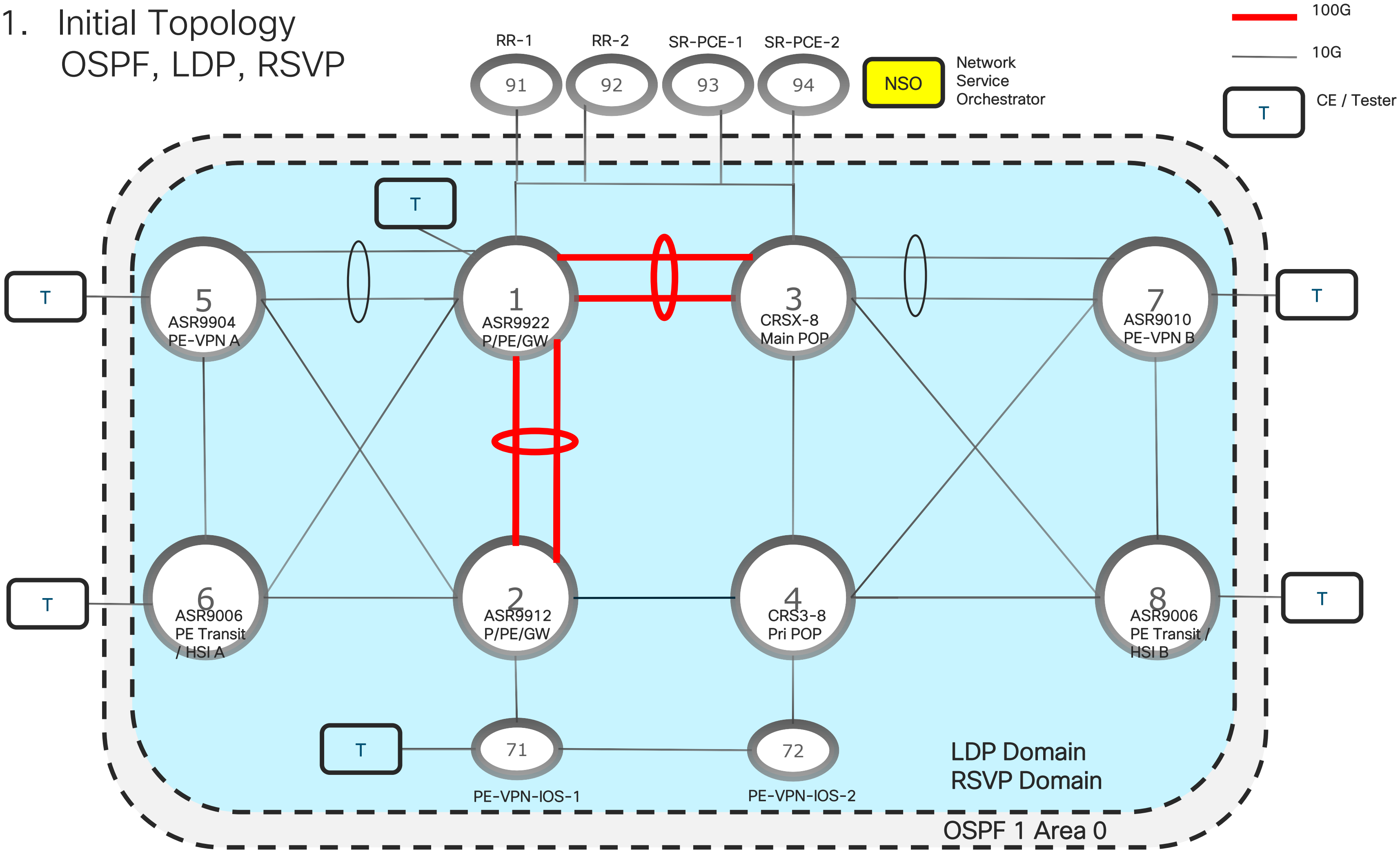
Device List

No	Device Function	Device Type	Software	Device Modul (Qty)
1	**P/PE-GW/SRMS**	ASR 9922	XR 6.6.2	RSP2-SE (1), SFC2 (4), MOD-400-SE (1), MPA 2x100GE (2), MOD-200-TR (1) MPA 20x10 (1), CPAK-100G-LR4 (4), SFP-10G (x)
2	**P/PE-GW/SRMS**	ASR 9912	XR 6.6.2	RSP2 SE (1), SFC2 (4), MOD-400-SE (1), MPA 2x100GE (2), MOD-200-TR (1) MPA 20x10 (1), CPAK-100G-LR4(3), SFP-10G (x)
3	**Main – CRS8**	CRS-X /8	XR 6.4.2	CRS-8-PRP-12G(1), 4x100GE (1), 40x10GE (1), CPAK-100G-LR4(3), SFP-10G (x)
4	**Primary- CRS8**	CRS-3 /8	XR 6.4.2	CRS-8-PRP-12G (1), 4x100GE (1), 14x10GE (1), CPAK-100G-LR4(2), XFP-10G (x)
5	**PE-VPN (A)**	ASR 9904	XR 6.6.2	RSP2-SE (1), MOD 160-SE (1), MPA 20x10 (1), SFP-10G (2)
6	**PE-Transit / HSI (A)**	ASR 9006	XR 6.6.2	RSP-880-SE (1), MOD 160-SE (1), MPA 20x10 (1), SFP-10G (2)
7	**PE-VPN (B)**	ASR 9010	XR 6.6.2	RSP-880-SE (1), MOD 160-SE (1), MPA 20x10 (1), SFP-10G (2)
8	**PE-Transit / HSI (B)**	ASR 9006	XR 6.6.2	RSP-880-SE (1), MOD 160-SE (1), MPA 20x10 (1), SFP-10G (2)
91 92	**RR-1** **RR-2**	ASR 1002-X ASR 1002-X	16.11	10Gig port (1 port), SFP-10G (1)
93 94	**SR-PCE-1** **SR-PCE-2**	XRv 9000 XRv 9000	XR 6.6.2	10GE port (1 port)
71 72	**PE-VPN-IOS-1** **PE-VPN-IOS-2**	ASR 1002-X ASR 1002-X	16.11	10Gig port (2 port), SFP-10G (2)
	NSO	Software	5.1	Network Service Orchestrator – Automation Software

Demo SDN Transport Scenario Test Case

You make networking **possible**

1. Initial Topology
OSPF, LDP, RSVP



Test Case Details

- 1: Initial Topology
  - TEST 1: OSPF LDP-RSVP Network Setup with NSO
  - TEST 2: L3VPN Service over LDP-RSVP Network with NSO
  - TEST 3: L2VPN Service over LDP-RSVP Network with NSO

Observe Challenge, Constraint and Complexity of

1. ldp - rsvp - 2 protocol vs SR 1 protocol - 50% simplification
2. ldp label number
   show mpls for | util wc line = 144 vs 23 - simplification for operation & tshoot
3. limitation rsvp path same for all vrf
4. limitation rsvp path same for all service in 1 vrf
5. limitation rsvp session stateful
6. no delay / latency path
7. complex frr / protection rely on rsvp - link, node, srlg

2. L3VPN Service

autocar vpn network slice
ldp lsp path

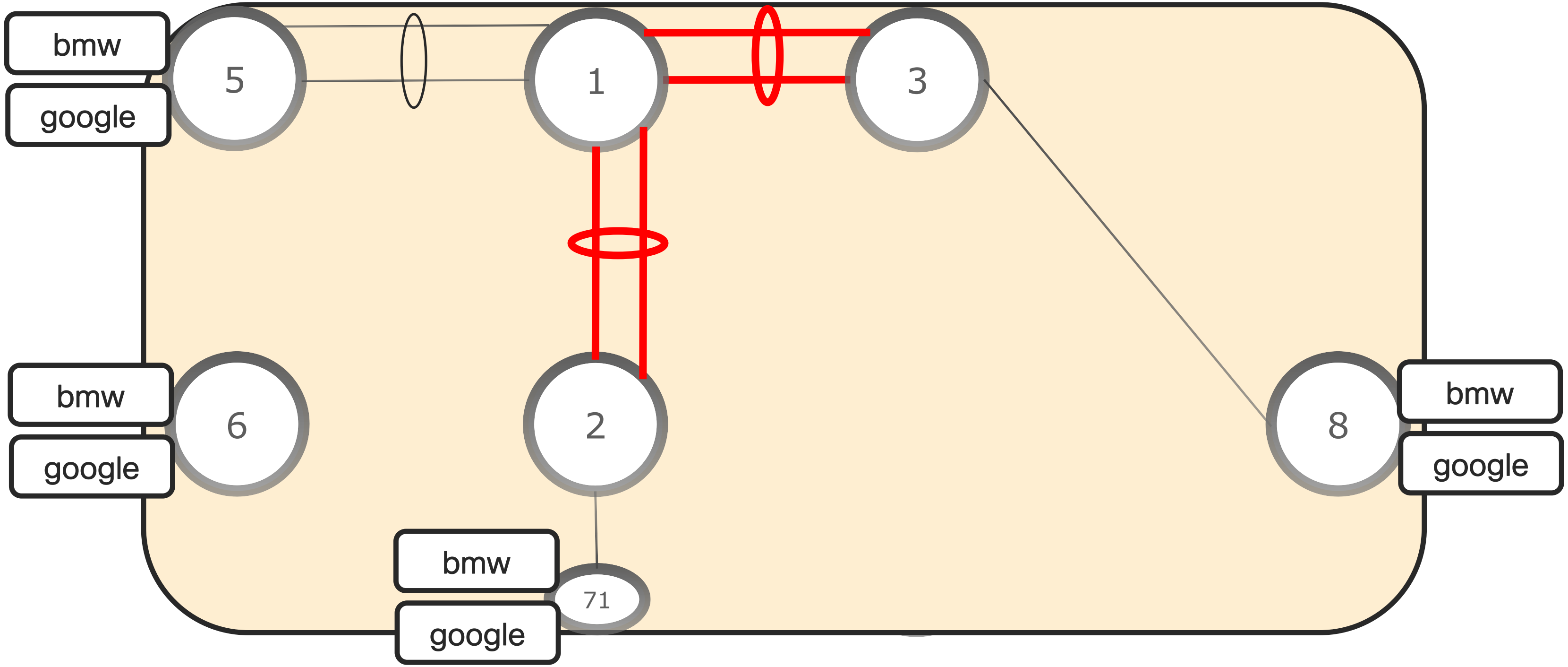
Postman
REST API

NSO Network Service Orchestrator

100G

10G

node slice — vpn service



2. L3VPN Service
5g vpn network slice
ldp lsp path

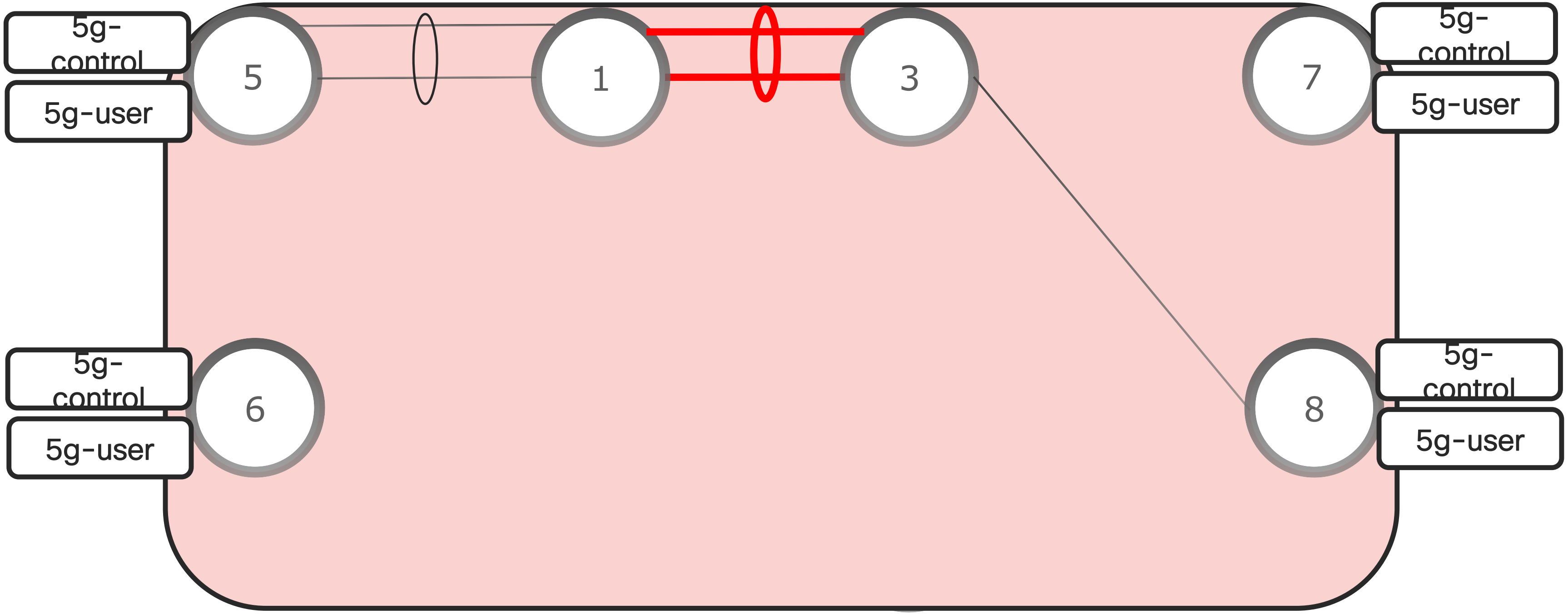
Postman REST API

NSO Network Service Orchestrator

100G

10G

node slice — vpn service



2. L3VPN Service

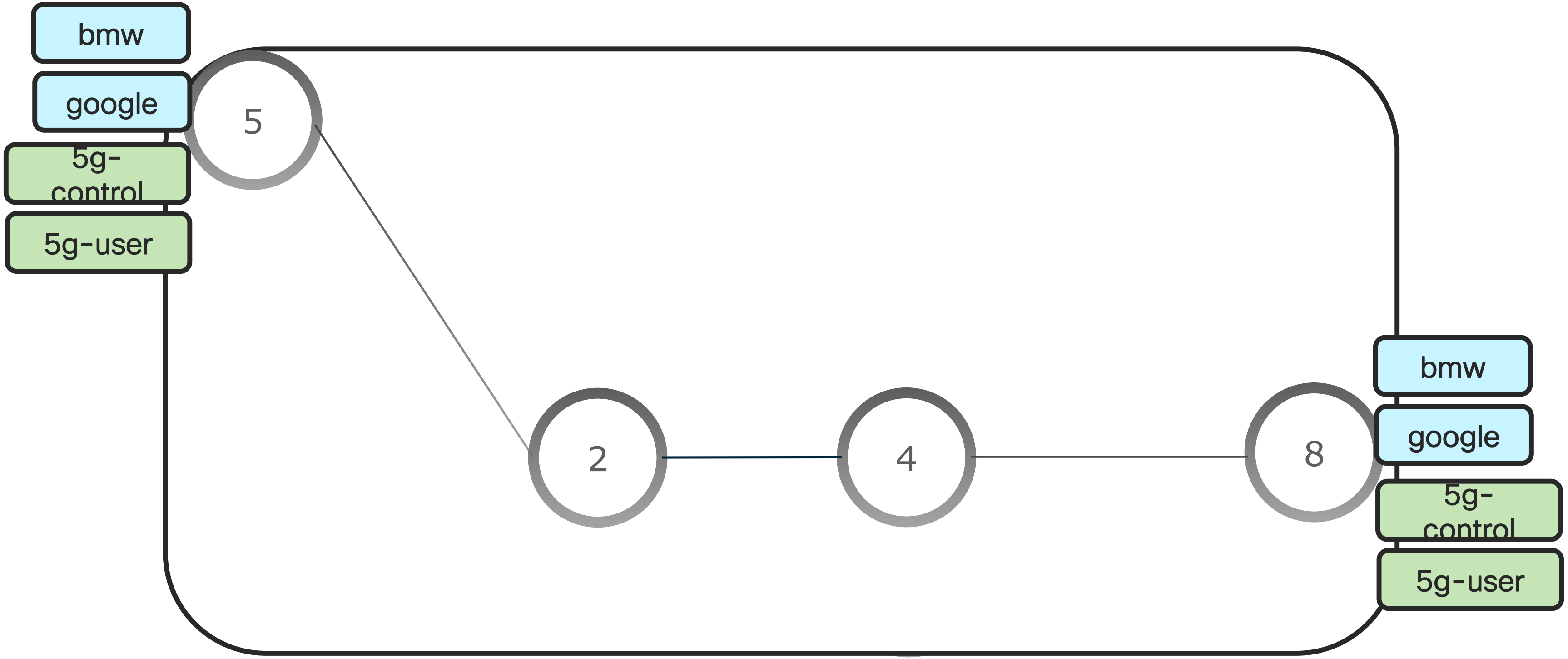
autocar vpn network slice
5g vpn network slice
rsvp-te lsp path

NSO Network Service Orchestrator

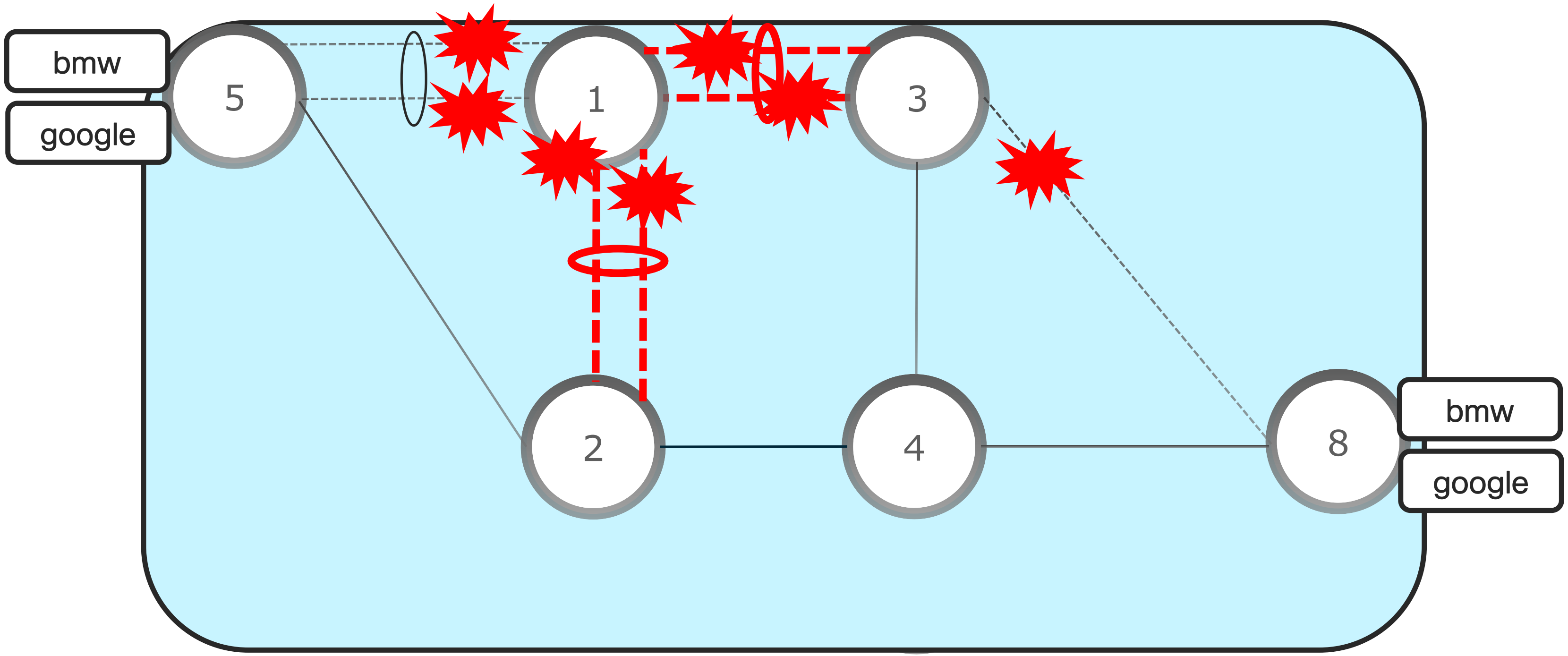
100G

10G

node slice vpn service



2. L3VPN Service
autocar vpn network slice
convergence after incident



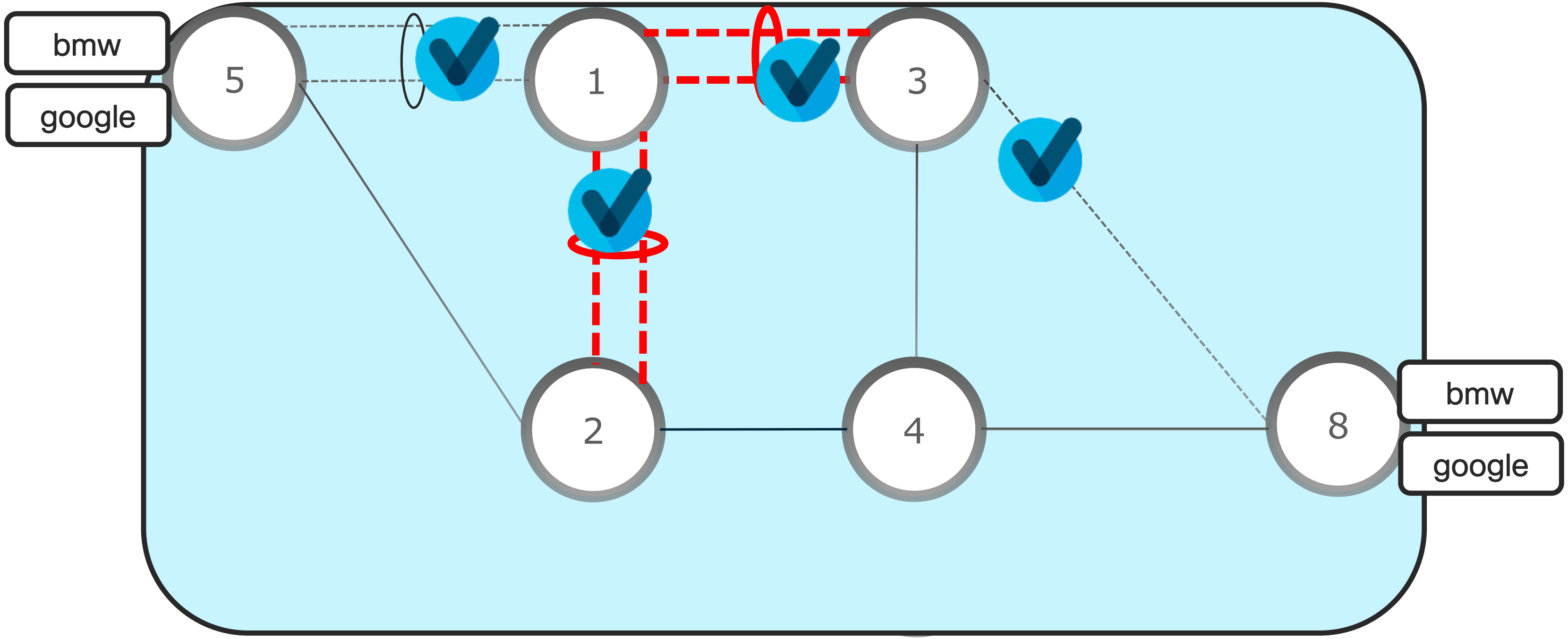
2. L3VPN Service
autocar vpn network slice
convergence after recovery

NSO Network Service Orchestrator

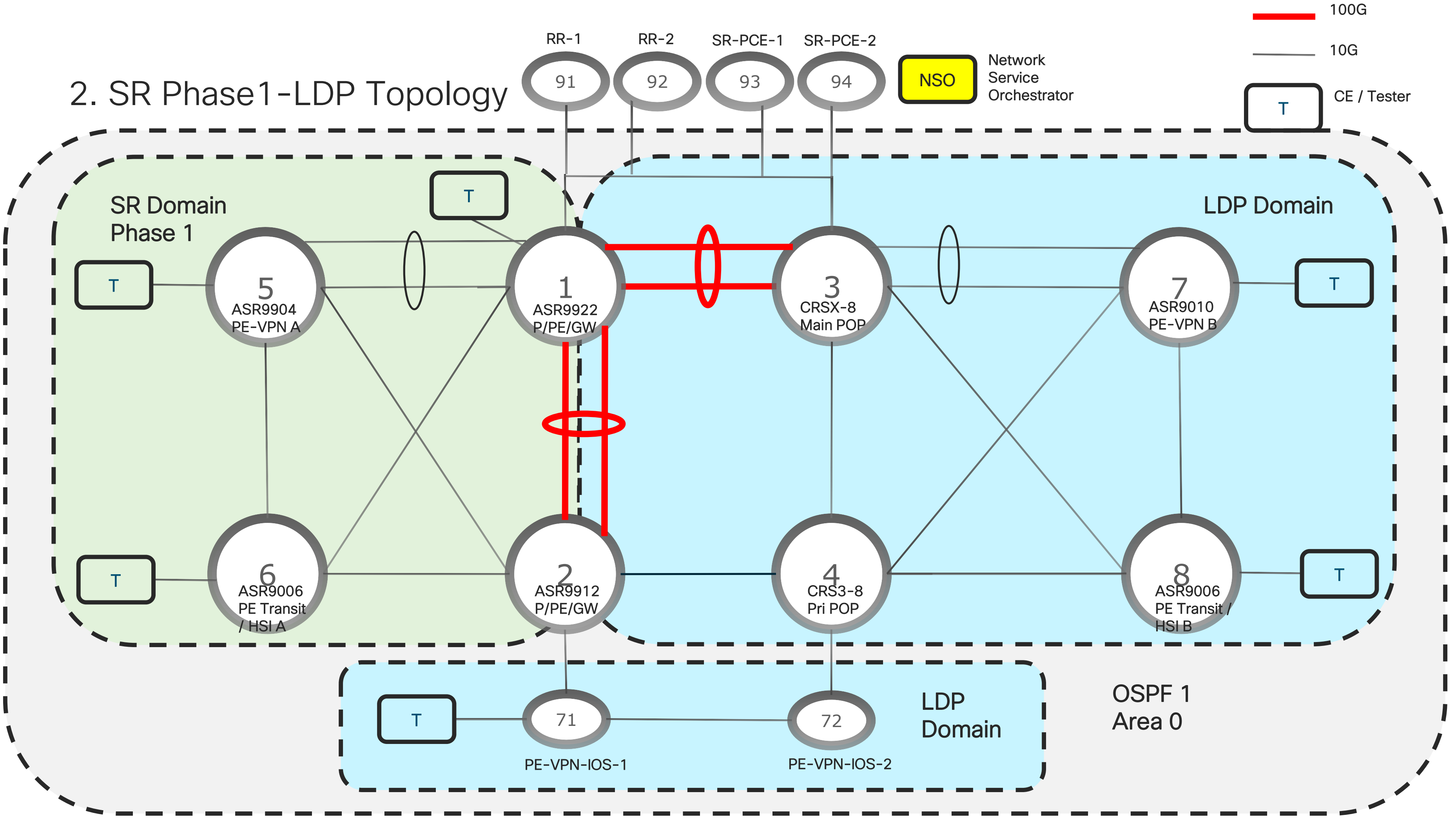
🟥 100G

— 10G

node slice: vpn service



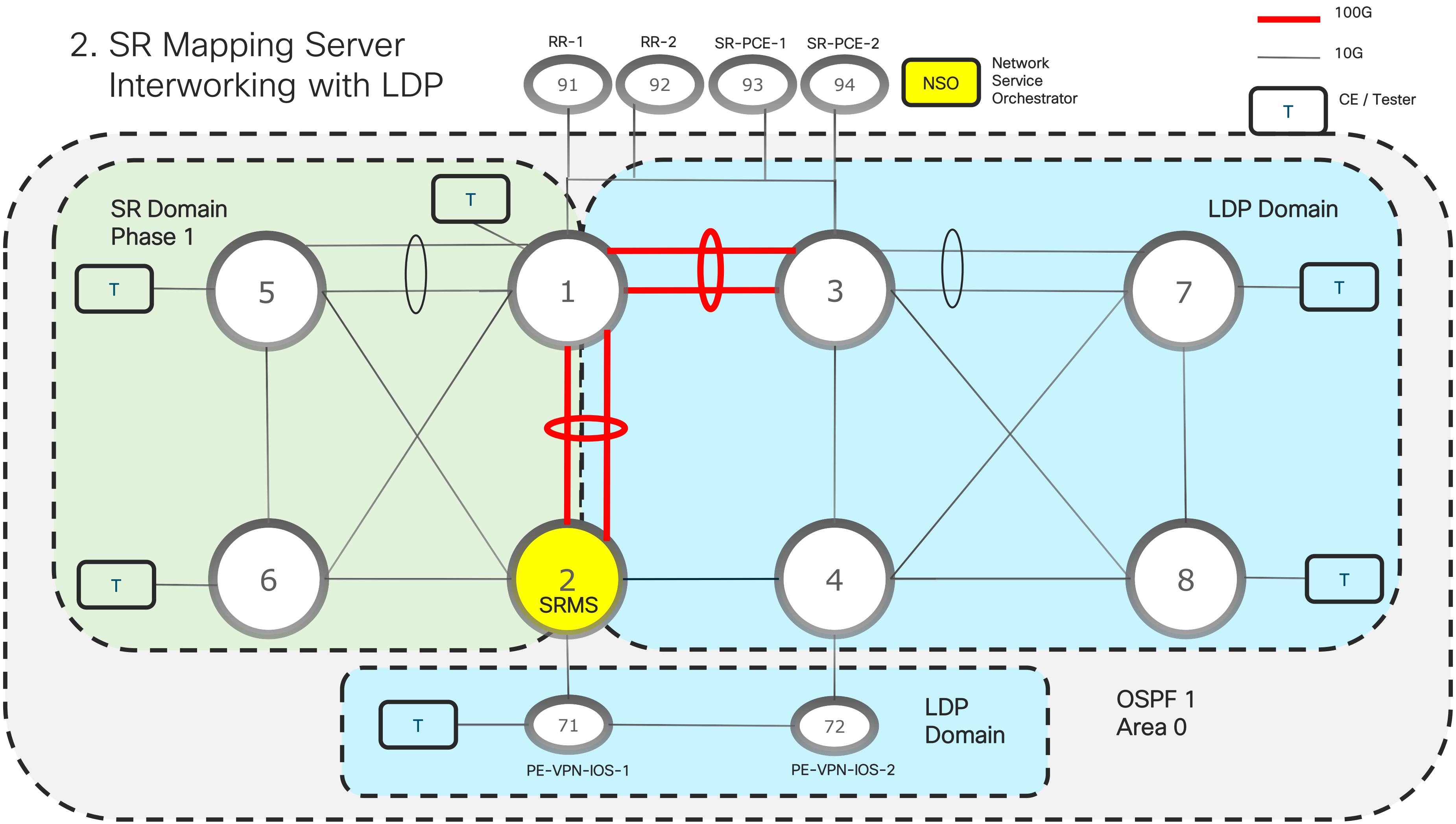
2. SR Phase1-LDP Topology



Test Case Details

- 2. SR Phase 1-LDP Topology
  - TEST 1: Phase 1 SR Configuration Preparation Before SR Migration (LDP Preferred)
  - TEST 2: SR Mapping Server Setup
  - TEST 3: Phase 1 SR Migration (SR Preferred / Remove LDP) and Interworking with LDP Domain
  - TEST 4: L3VPN Service over SR-LDP Topology
  - TEST 5: L2VPN Service over SR-LDP Topology

2. SR Mapping Server Interworking with LDP



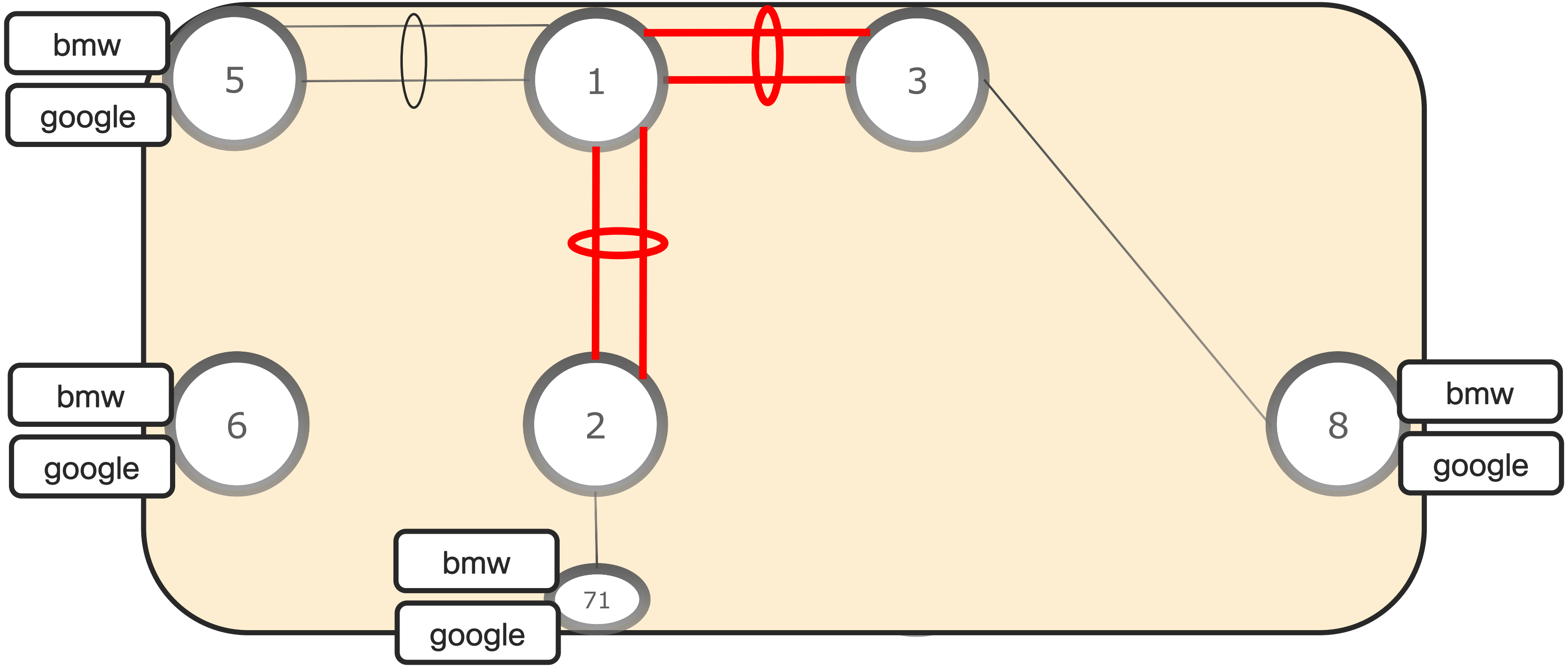
2. L3VPN Service
autocar vpn network slice
seamless sr+ldp lsp path

100G

10G

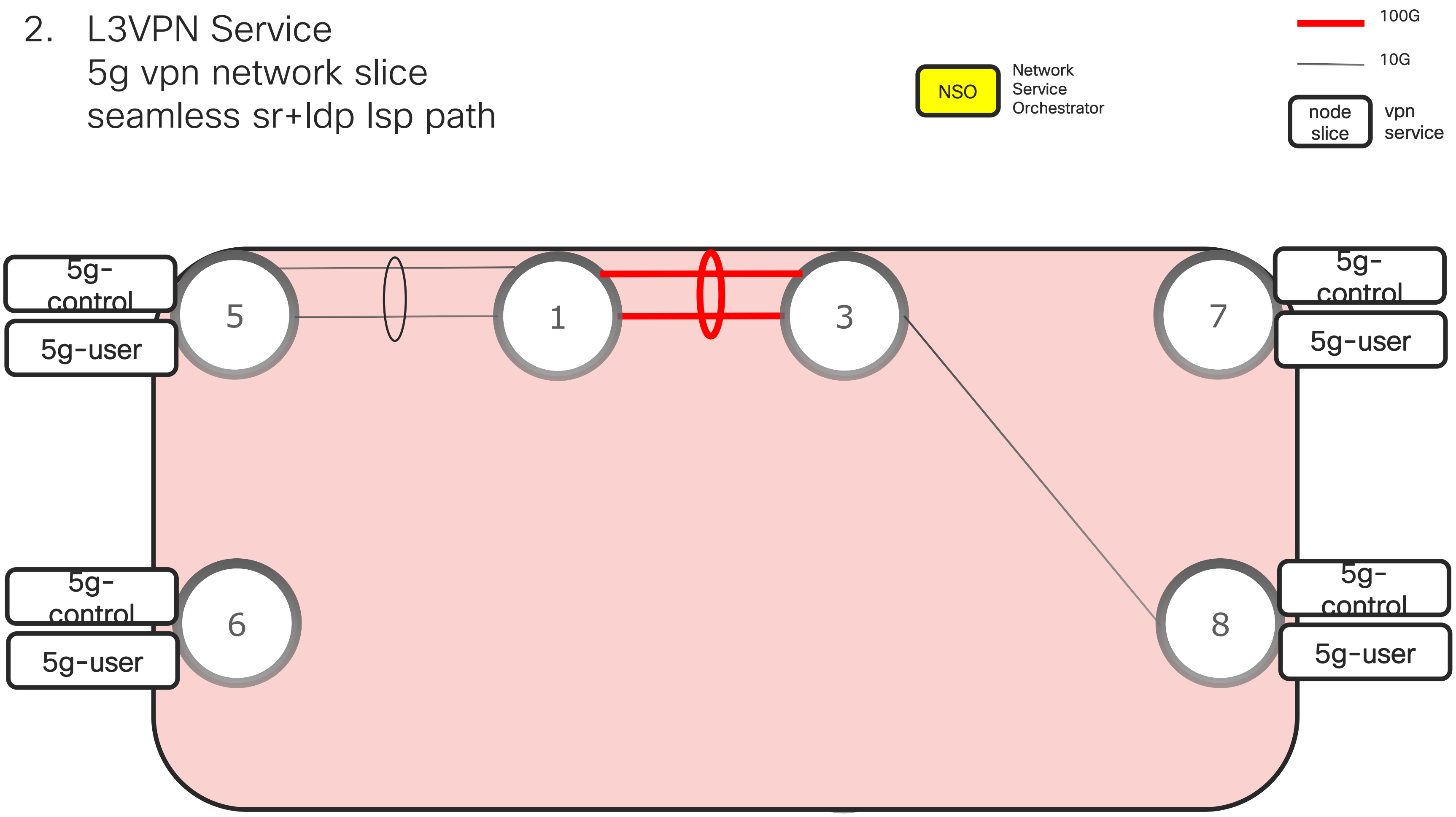
NSO Network Service Orchestrator

node slice vpn service

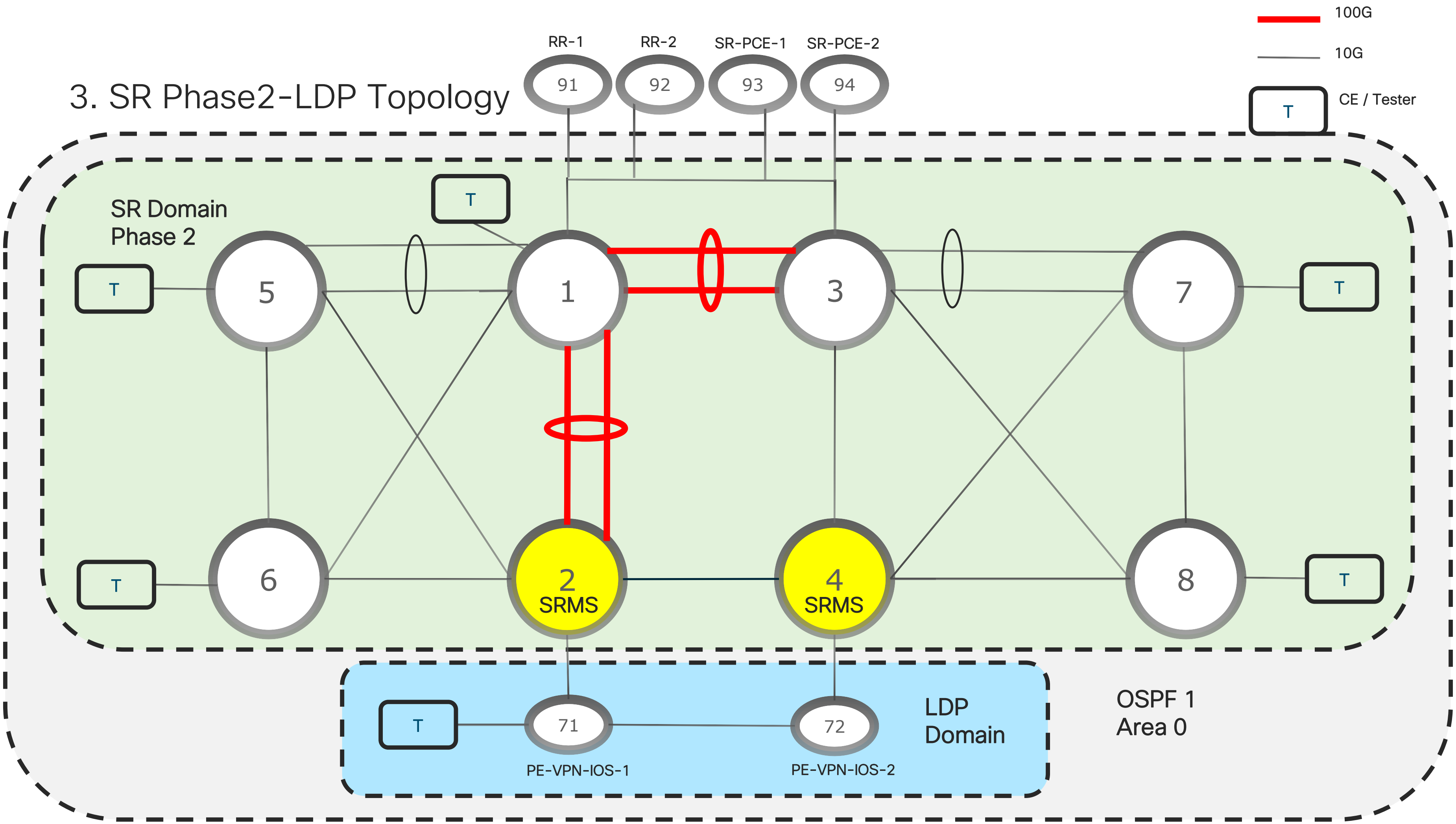


2. L3VPN Service
5g vpn network slice
seamless sr+ldp lsp path

NSO Network Service Orchestrator



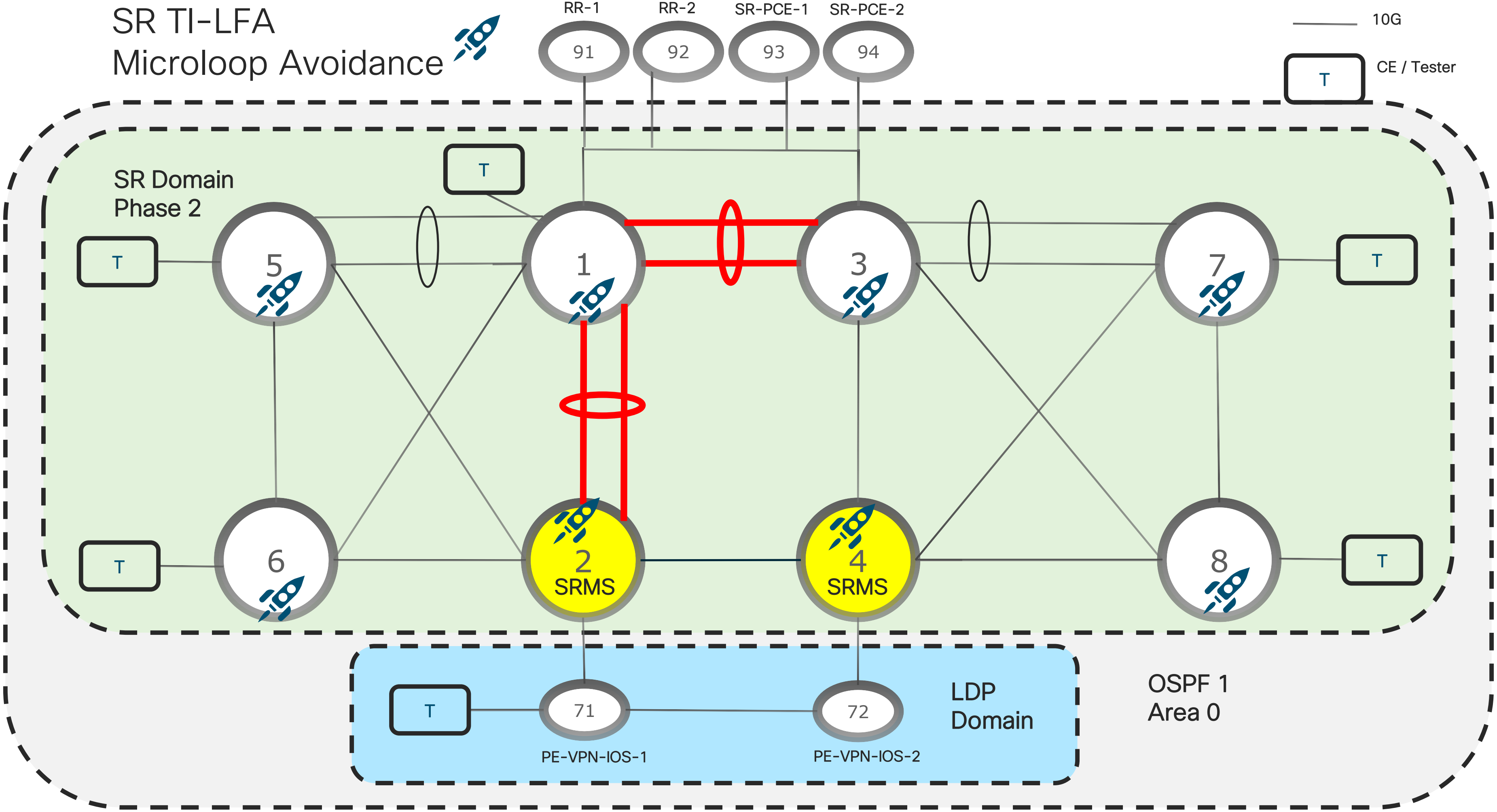
3. SR Phase2-LDP Topology



Test Case Details

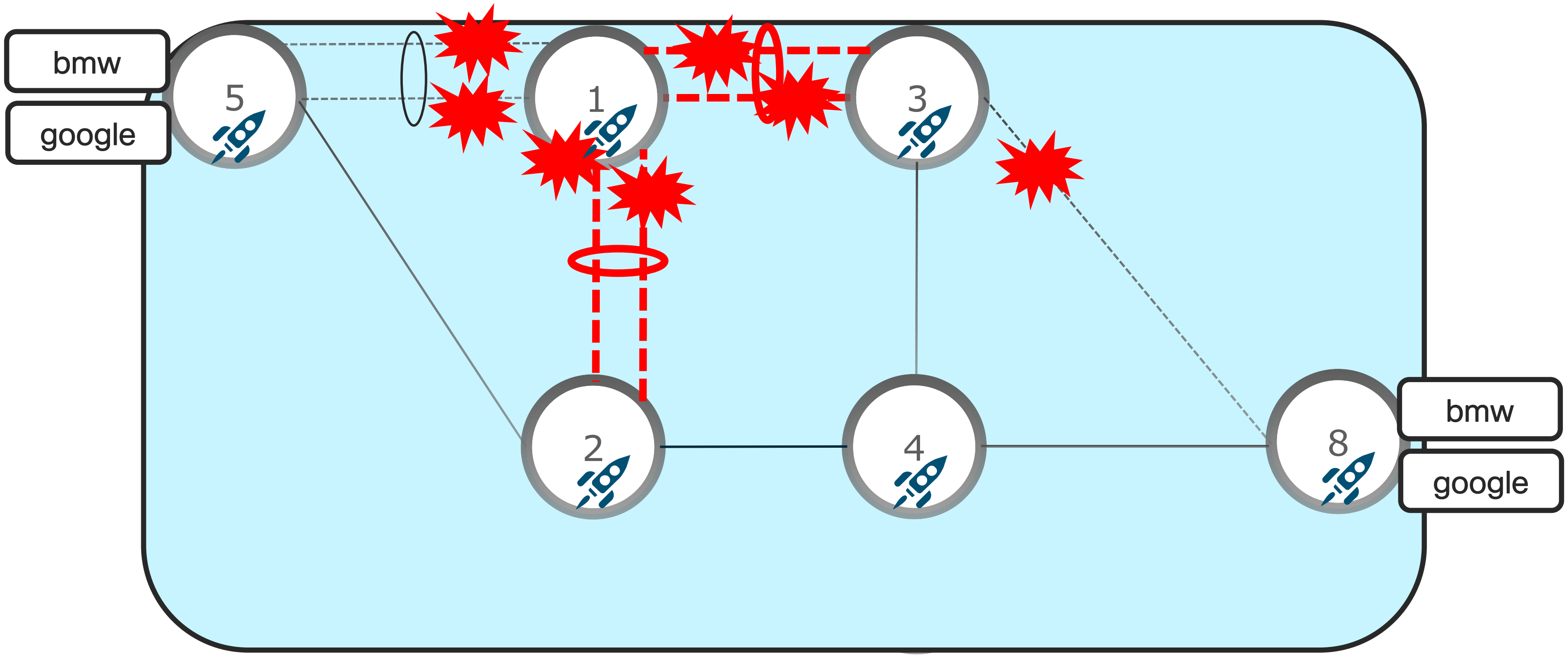
- 3. SR Phase2-LDP Topology
  - TEST 1: Phase 2 SR Migration (SR Preferred / Removed LDP)
  - and Interworking with LDP Domain (PE-VPN-IOS)
  - TEST 2: Auto Protection with SR-TILFA
  - TEST 3: L3VPN Service over SR-LDP Topology (PE-VPN-IOS) with SR Mapping Server
  - TEST 4: L2VPN Service over SR-LDP Topology (PE-VPN-IOS) with SR Mapping Server
  - TEST 5: SR-PCE, PCEP and BGP LS Setup
  - TEST 6: Network Slicing – L3VPN Service over SR On Demand Nexthop with Low Latency
  - TEST 7: Network Slicing – L2VPN service over SR On Demand Nexthop with Low Latency

3. SR Phase2-LDP Topology
SR TI-LFA
Microloop Avoidance



3. L3VPN Service

autocar vpn network slice
ti-lfa + microloop avoidance
convergence after incident



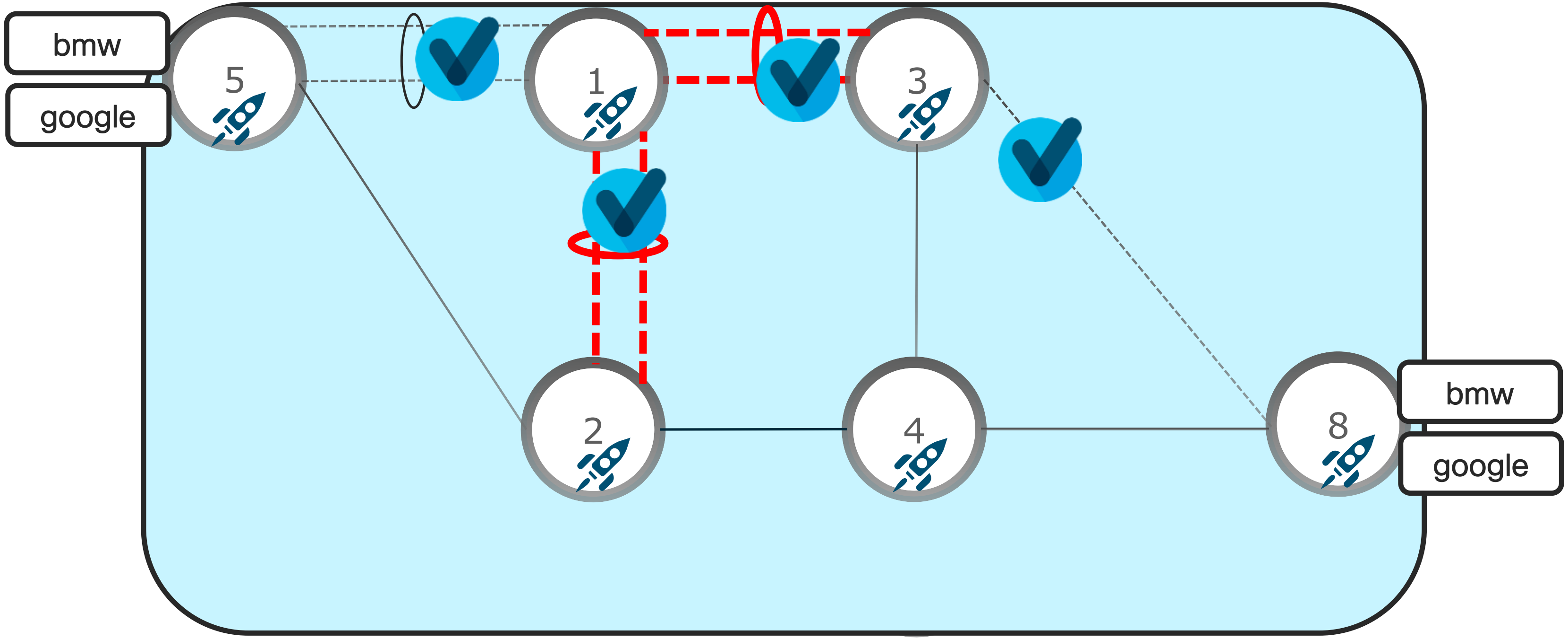
3. L3VPN Service
autocar vpn network slice
ti-lfa + microloop avoidance
convergence after recovery

NSO Network Service Orchestrator

100G

10G

node slice vpn service



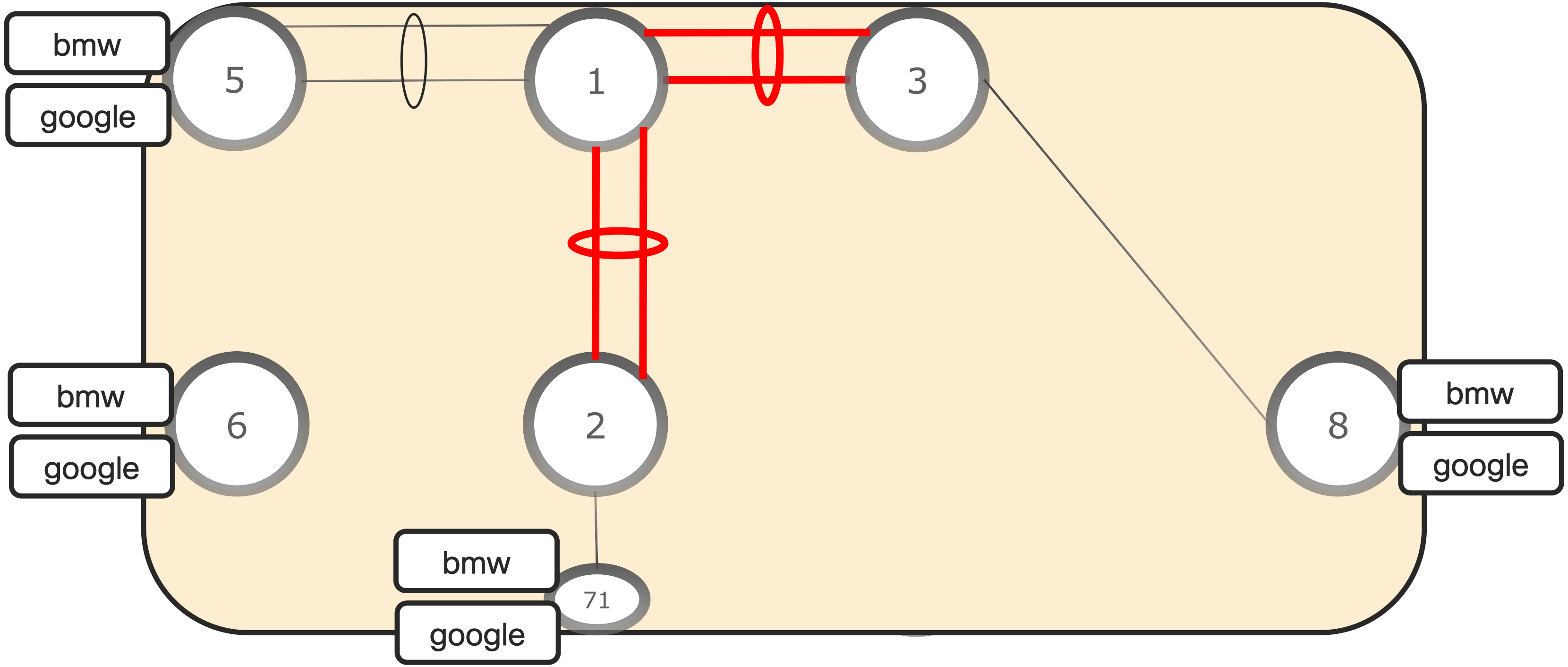
3. L3VPN Service
autocar vpn network slice
seamless sr+ldp lsp path

NSO Network Service Orchestrator

100G

10G

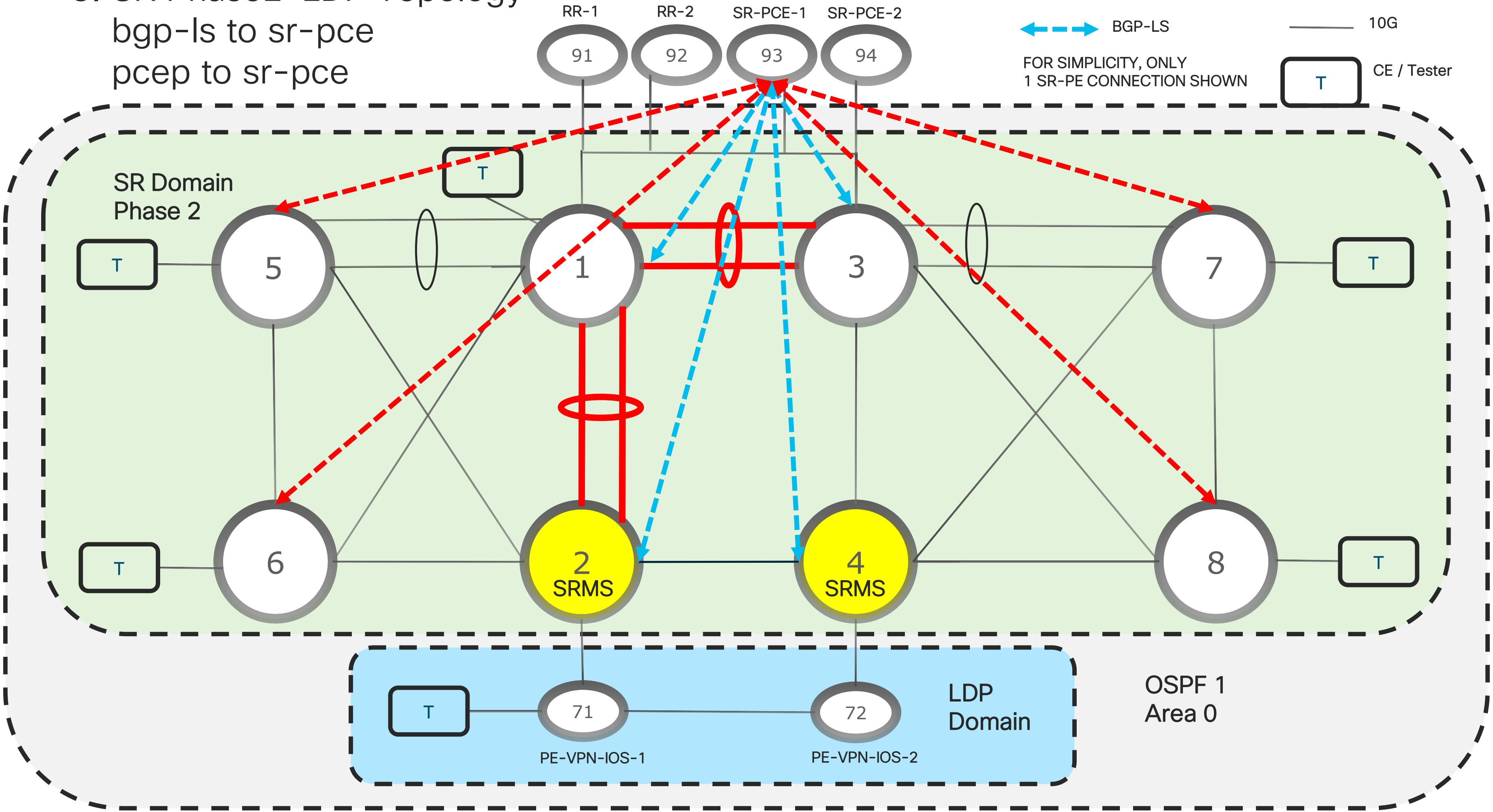
node slice vpn service



3. SR Phase2-LDP Topology

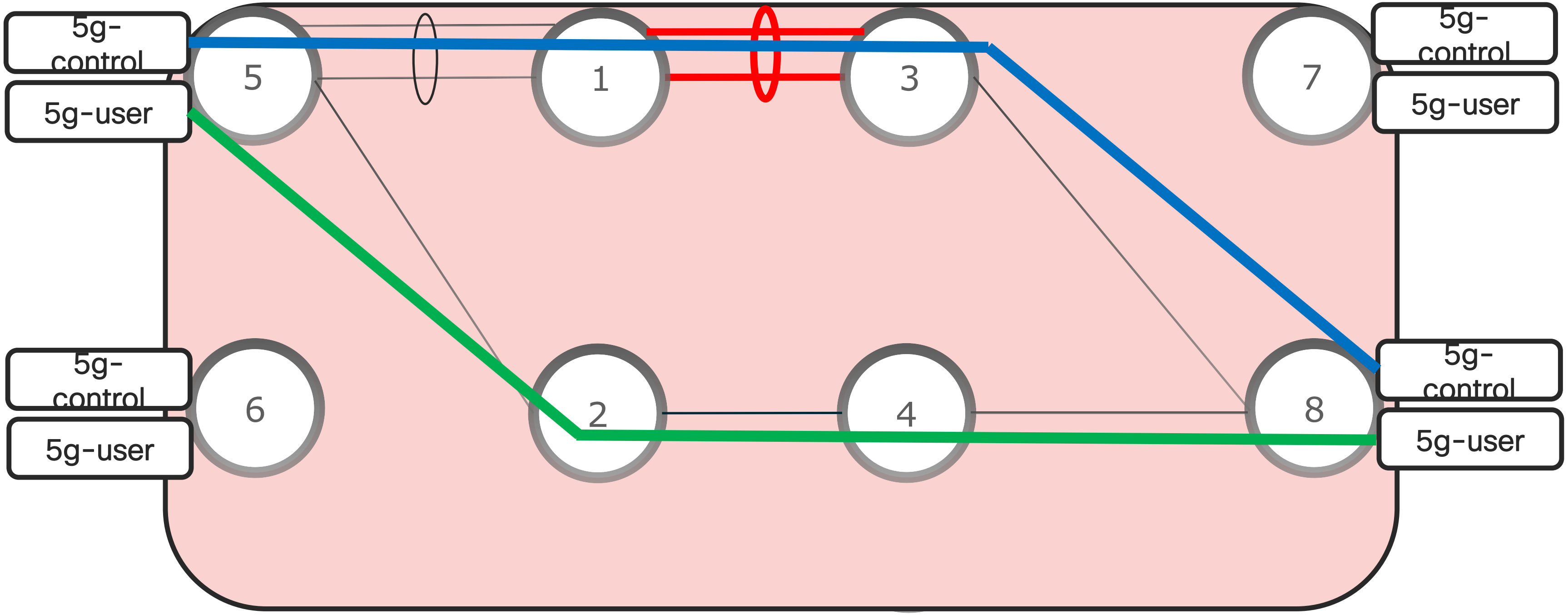
bgp-ls to sr-pce

pcep to sr-pce

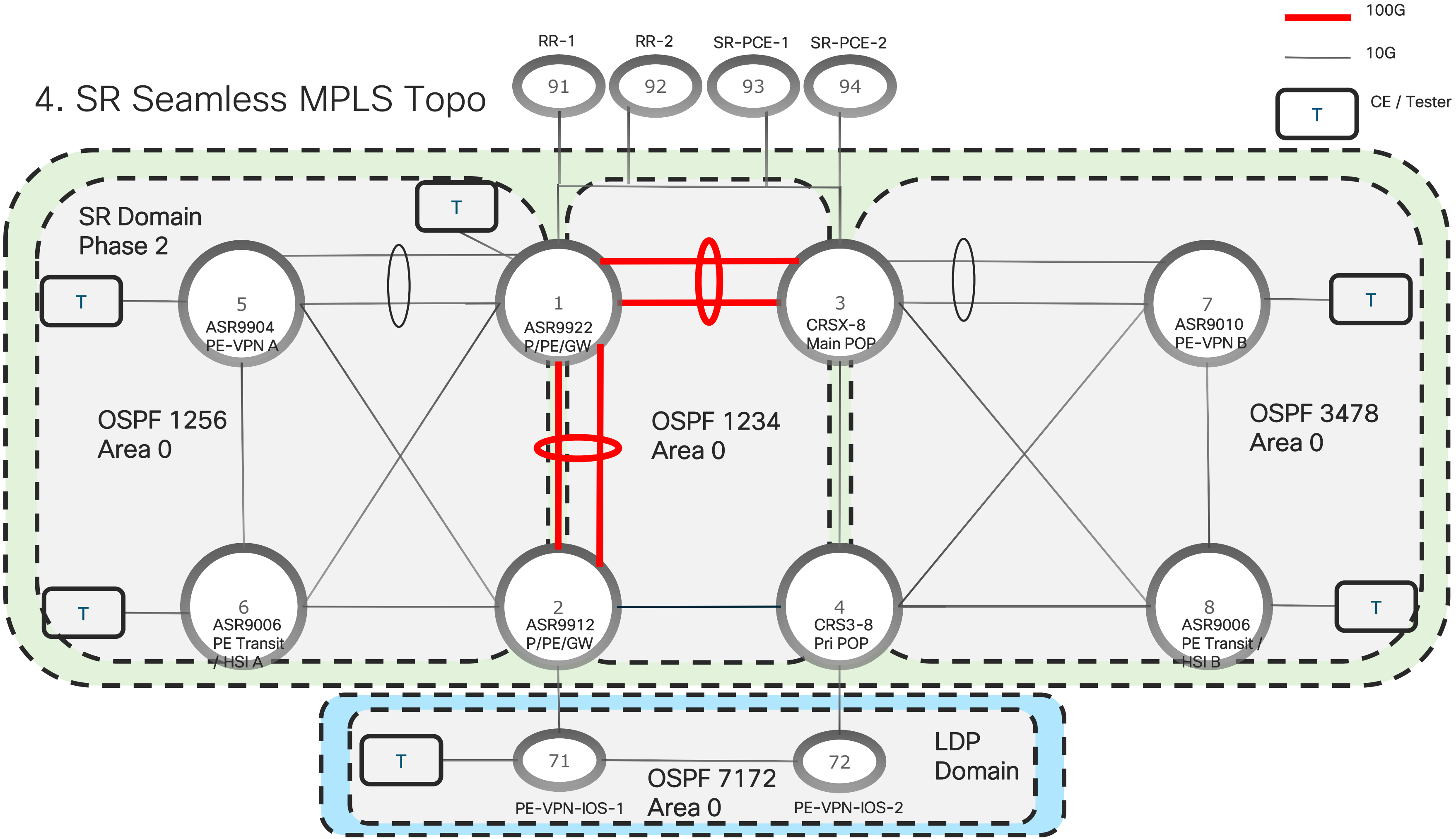


2. L3VPN Service

5g vpn network slice
sr-odn low latency → 5g control
sr-odn high bw → 5g user



4. SR Seamless MPLS Topo

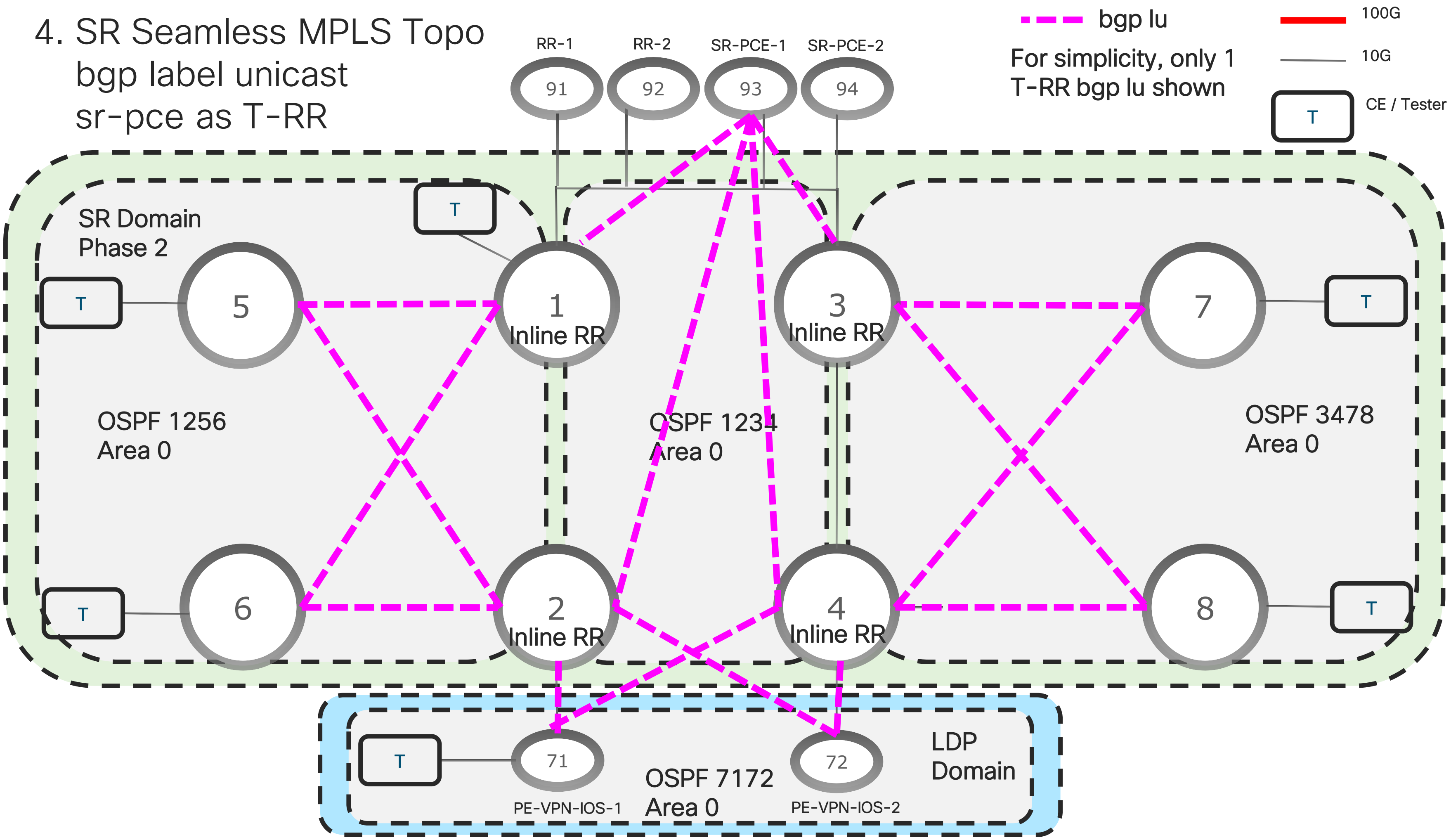


Test Case Details

- 4. SR Seamless MPLS Topology
  - TEST 1: Multi OSPF Domain Setup (4 x OSPF process-id Area 0)
  - TEST 2: BGP-LU setup and BGP Prefix-SID
  - TEST 3: Remove SR Mapping Server for Interworking SR-LDP
  - TEST 4: Network Slicing L3VPN Service over SR-LDP Seamless MPLS
  - TEST 5: Network Slicing L2VPN Service over SR-LDP Seamless MPLS

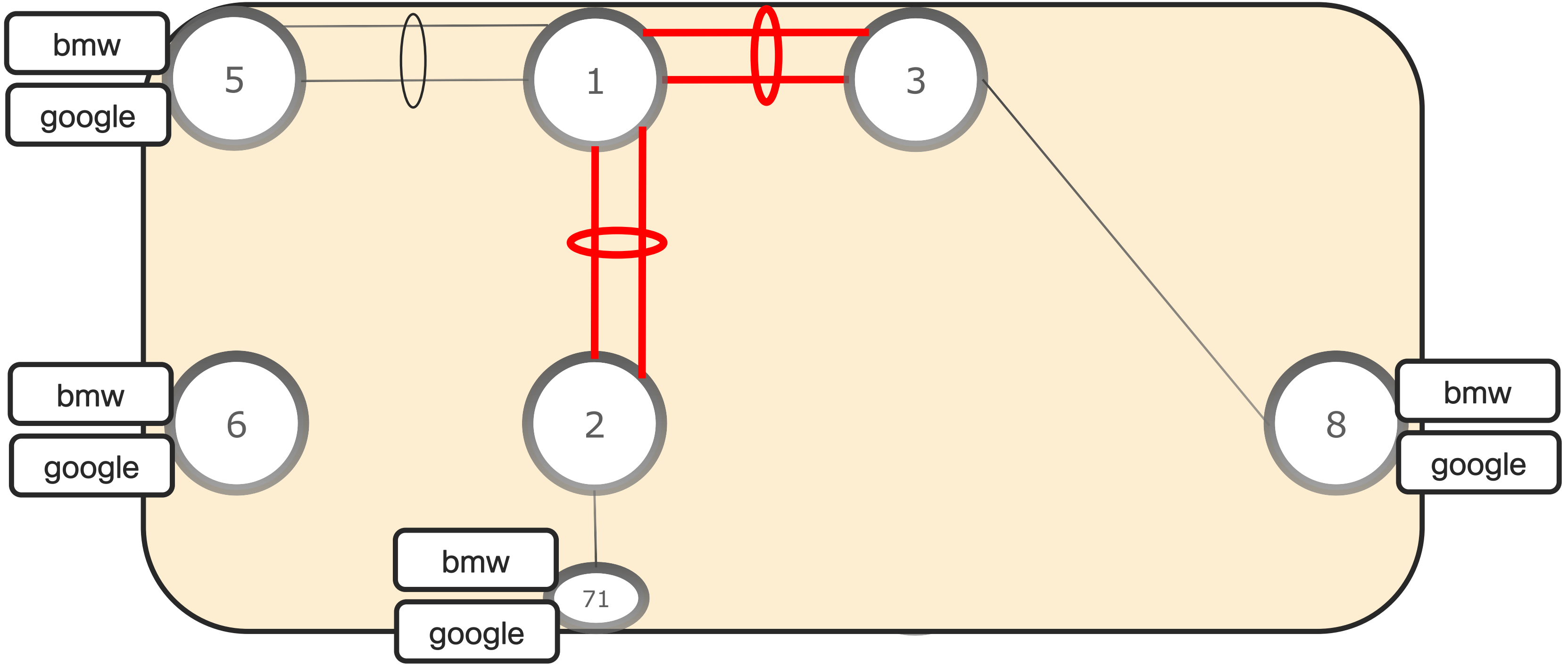
  - **ONLY FOR SR DOMAIN**
  - TEST 6: SR-PCE, PCEP & BGP-LS Setup
  - TEST 7: Remove BGP-LU
  - TEST 8: Network Slicing L3VPN Service over SR-PCE Seamless MPLS
  - TEST 9: Network Slicing L2VPN Service over SR-PCE Seamless MPLS

4. SR Seamless MPLS Topo
bgp label unicast
sr-pce as T-RR



For simplicity, only 1 T-RR bgp lu shown

4. L3VPN Service autocar vpn network slice over seamless mpls + bgp lu seamless sr+ldp lsp path



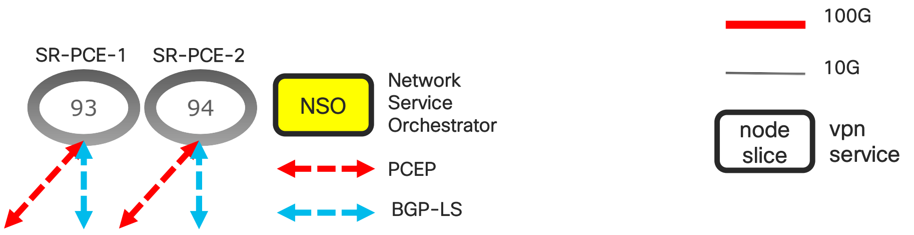
4. L3VPN Service

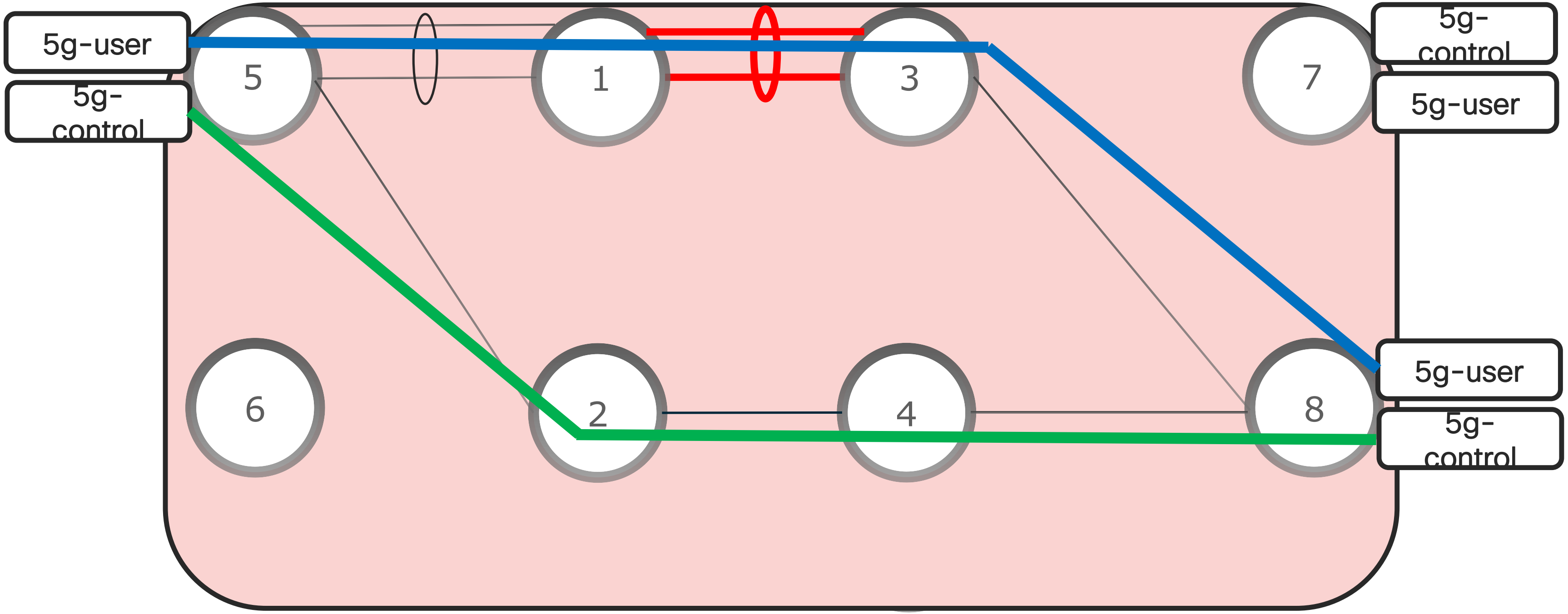
5g vpn network slice

over seamless mpls + bgp lu

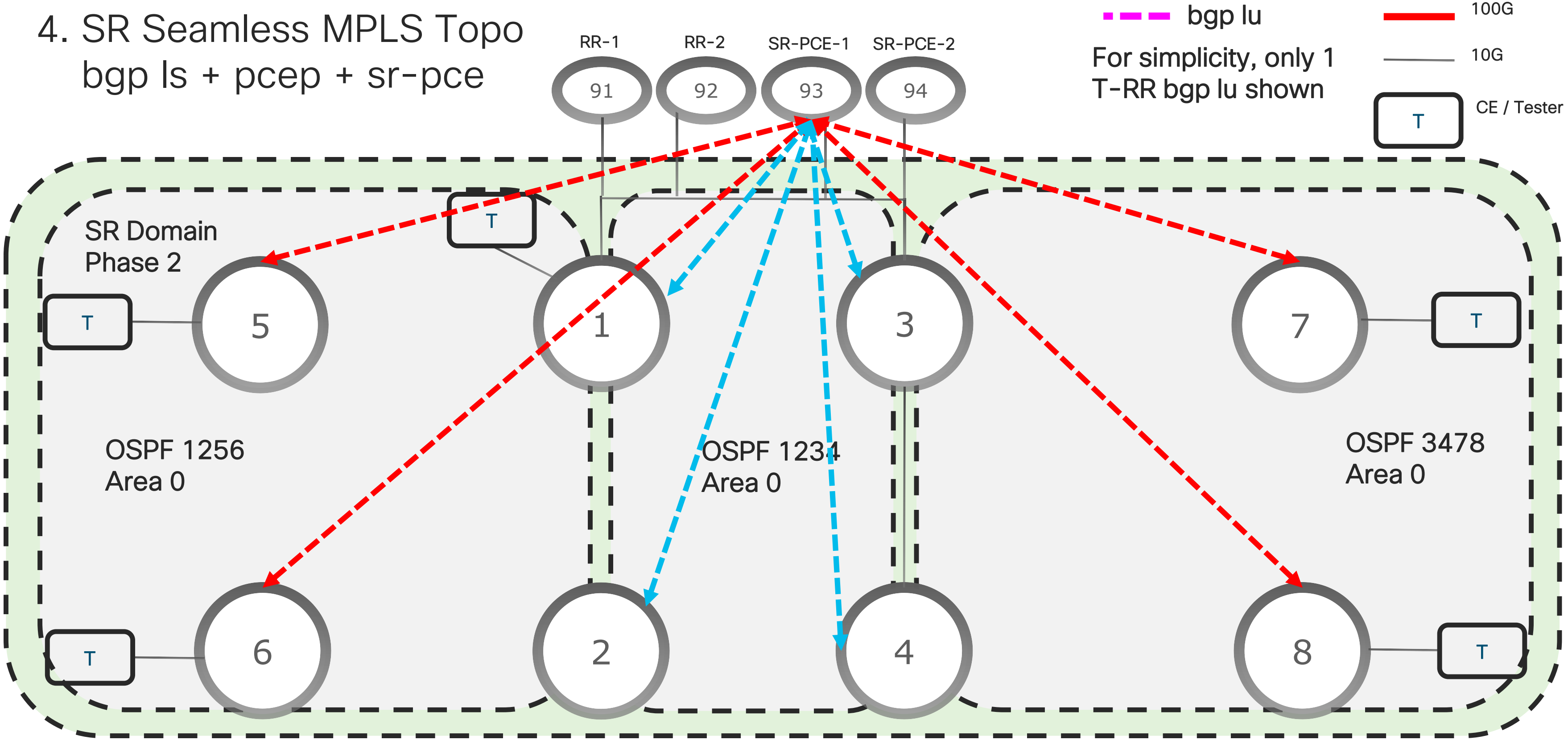
sr-odn low latency → 5g control

sr-odn high bw → 5g user





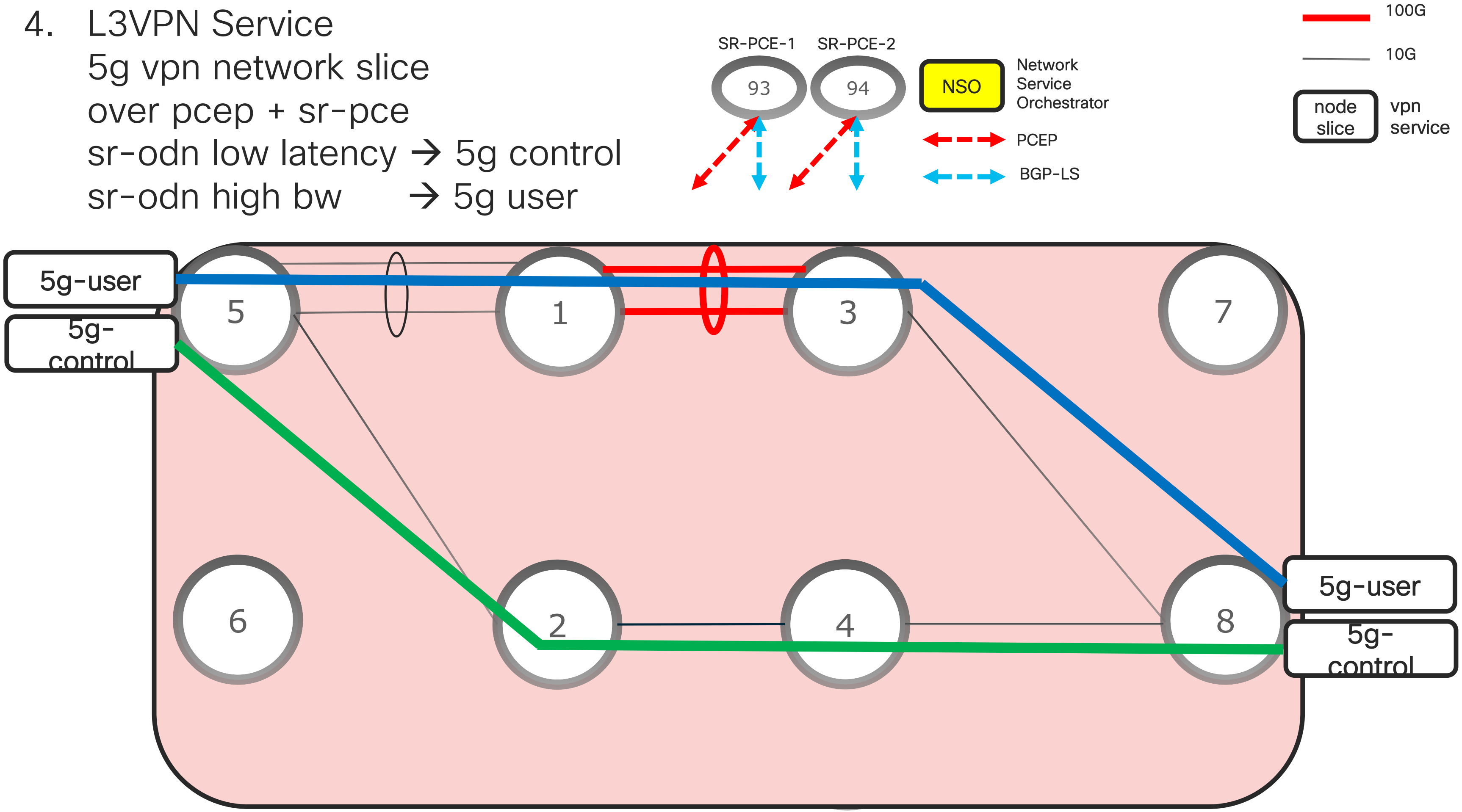
4. SR Seamless MPLS Topo
bgp ls + pcep + sr-pce



For simplicity, only 1 T-RR bgp lu shown

4. L3VPN Service

5g vpn network slice
over pcep + sr-pce
sr-odn low latency → 5g control
sr-odn high bw → 5g user



Reference Material

SP Validated Designs Home Page:

- https://xrdocs.github.io/design/

Converged SDN Transport (Metro Fabric) HLD

- https://xrdocs.github.io/design/blogs/latest-metro-fabric-hld/

Topology & Configs

- https://github.com/ios-xr/design/tree/master/

Cisco Converged SDN Transport Whitepaper

- "Cisco 5G xHaul Transport" White paper
  - 5G xHaul WP (HTML): https://www.cisco.com/c/m/en_us/network-intelligence/service-provider/digital-transformation/converged-5g-xhaul-transport.html?cachemode=refresh
  - 5G xHaul WP (PDF): https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/mobile-internet/white-paper-c11-741529.pdf
- Lightreading ”Cisco 5G xHaul Transport” webinar and whitepaper
  - https://www.lightreading.com/webinar.asp?webinar_id=1324
  - https://www.lightreading.com/lg_redirect.asp?piddl_lgid_docid=748878&piddl_lg_pcode=wprightcolumn
- "Cisco 5G xHaul Transport" Podcast
  - https://packetpushers.net/podcast/weekly-show-417-meeting-5g-demands-with-ciscos-5g-xhaul-transport-sponsored/
- “5G xHaul Transport” Cisco Knowledge Network (CKN) webinar recording
  - https://www.cisco.com/c/m/en_us/network-intelligence/service-provider/digital-transformation/knowledge-network-webinars.html

Additional Resources

- Cisco 5G Page: www.cisco.com/go/5g
- Cisco’s SP Mobility Page:
  - https://www.cisco.com/c/en/us/solutions/service-provider/mobile-internet/index.html
- Compass "Metro Fabric Design” : https://xrdocs.io/design/
- Segment Routing Information:
  - https://www.cisco.com/c/en/us/solutions/service-provider/cloud-scale-networking-solutions/segment-routing.html
  - www.segment-routing.net
- Cisco Telco Page:
  - http://www.cisco.com/go/telco
- Cisco 5G Security White Paper: https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/service-provider-security-solutions/5g-security-innovation-with-cisco-wp.pdf
- Cisco EPN5.0 & EPN4.0:
  - https://www.cisco.com/c/en/us/solutions/enterprise/design-zone-service-provider/programmable-network.html

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